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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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SOCIETY OF AUTOMOTIVE ENGINEERS INC.
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Balloon Tires Were Never Intended to Absorb Big Bumps

THE great advantage of balloon tires over high-pressure tires is that the low pressure of the balloon enables the tire to swallow up and absorb minor bumps and light impacts—impacts which the high pressure tire could not swallow, but would transmit.

But the balloon tire should not be permitted to swallow up and absorb big bumps and heavy impacts. For if we do permit our tire to absorb these heavy impacts, we then have no means of dissipating the energy absorbed and our ride becomes an extremely bouncing and galloping affair. And no manner of check against spring recoil can possibly prevent this bouncing and galloping because it is not spring recoil which is causing it. It is caused by tire recoil.

The only way to prevent vicious tire recoil is to prevent vicious tire compression. And the only way to prevent vicious tire compression is to provide a spring of sufficient suppleness to act instead of the tire. If the spring is sufficiently supple, it will yield readily and thus prevent the tire from yielding abnormally. The reason for having a big bump absorbed by the spring instead of by the tire is simply because it is possible to adequately control the recoil of a spring, whereas it is impossible to control, in any way, the recoil of a tire.

We know of several manufacturers who are starting to equip with balloon tires and at the same time they are stiffening up their front springs. Naturally, the front-end galloping of these cars is excessive. Then these manufacturers are attempting to lessen this galloping by installing checks which are designed to control recoil of the springs. This gets them nowhere because no spring action has taken place and hence there is no spring recoil to be controlled. Obviously you can't control tire recoil by hooking up something to the springs.

The simple and only possible remedy for all of this galloping and front-end bobbing and "shimmy" is to absorb your vicious impacts in a member from which the energy stored may be dissipated. Throw away your 450-pound front springs and get the rate down to from 250 to 300 pounds per inch of deflection. Then hook up Stabilators which properly control spring recoil and you will be astounded at the complete roadability you have given to your cars. Naturally you will have to provide more travel for these more supple front springs. Your rear springs are already plenty supple. In fact, you can afford to stiffen up your rear springs a little without destroying your roadability. And this slight stiffening of the rear springs will make them less susceptible to load variations.

President

JOHN WARREN WATSON COMPANY
TWENTY-FOURTH AND LOCUST STREETS
PHILADELPHIA
(Detroit Branch: 51-53 Canfield Avenue, East)

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Motorbus, Truck and Rail-Car

EACH succeeding year finds the commercial motor-vehicle transporting an increased share of the world's goods and its people. As the applications of automotive equipment are extended, so also are the engineering problems of its operation and maintenance multiplied. The designing engineer and the motor-transport engineer will solve these problems best through cooperative action. Such cooperative action is fostered by the annual Automotive Transportation Meeting of the Society. This important meeting convenes this year in New York City on Sept. 18 and 19. A full description of the program is given on p. 180.

Extent of Use of S.A.E. Data Sheets

THE exact extent to which the S.A.E. HANDBOOK as a whole is used is, of course, difficult to determine. The fact that 114 out of 122 manufacturers, this number including all but 6 of the manufacturers responsible for 98 per cent of the total automobile production in this Country, use the S.A.E. Charts of Physical Properties of Steels makes it clear that the S.A.E. HANDBOOK is serving its purpose excellently well in one of the most fundamental and significant phases of automobile design and construction. Some of the S.A.E. Standards are used practically universally and many of them have been reduced to practice generally. The reported returns to the questionnaire recently sent out by the Standards Department on the physical properties charts referred to above, as given on p. 184, are well worth reading.

Progress in Research

A BRIEF summary of research activities of the Society and a report of progress achieved during the April-July period will be found on pp. 182 and 183 of this issue. This material is presented in the belief that many of the members who for one reason or another are unable to maintain close touch with this important work will be interested to read the account and to know of the plan to print similar reports from time to time in these columns.

Riding-qualities, fuels, dilution, transportation costs, factors in tire design and air contamination by automobile-engine exhaust-gas are among the important items under active consideration by the Research Committee, of which H. L. Horning is chairman. Research projects relating to highways are receiving the attention of the Highways Committee, of which Past-President Bachman is chairman. The Research Department acts cooperatively with the committees in furtherance of the projects.

The Transactions

AS this issue of THE JOURNAL goes to press, copies of Part I of Vol. 18 of THE TRANSACTIONS are being mailed to the 536 members who have placed orders for them. The papers presented at the 1923 Annual Meeting and the Service, the Tractor and the Automotive Transportation meetings of the Society held last year, and papers presented at Sections meetings and printed in the January to June, 1923, issues of THE JOURNAL inclusive, that were considered by the Publication Committee to possess sufficient engineering value to warrant reprinting are included in this Part of THE TRANSACTIONS, together with the discussion of the papers. The volume consists of 949 pages.

This is the first Part of THE TRANSACTIONS to be distributed to the members upon payment of a charge of $2 per Part, the distribution without charge other than the payment of the regular dues having been discontinued with Part II of Vol. 17, covering THE TRANSACTIONS for the last half of 1922, in accordance with the resolution adopted by the Council at its meeting held in March, 1922.

Flexible-Discs Need Standardizing

A REAL need for standardization is indicated by the summary made for the Parts and Fittings Division of the dimensions of small flexible-discs used for generator, magneto and water-pump drives. The table on p. 188, which lists the variations in size of the 3-in. flexible-discs reported, shows that but 2 out of 13 discs have the same dimensions, although 10 of the 13 have the same bolt-hole diameter. The complete survey indicates that 48 different sizes of disc are used by 54 companies.

The need for standardization, or simplification as it might be better called in this case, is so evident that no difficulty should be experienced in having the standard that will eventually be approved by the Society adopted

in actual practice. Although it may seem undesirable for a company using a certain size of disc to change to a disc of slightly different dimensions, the servicing advantages of using a disc that can be obtained at any garage should more than outweigh the disadvantage and temporary expense of carrying two sizes of disc in stock resulting to the car manufacturer during the transition period.

Relating to Production

GOOD progress is being made in the procurement of papers for the Production Meeting of the Society which is to be held in Detroit, Oct. 22 to 24. To assure the selection of topics holding current interest for the papers and the discussions, some 20 representative production executives have assisted the Meetings Committee by submitting valuable suggestions based on the problems they are actually encountering in motor-vehicle factories at this time. Papers have been secured on the subjects of automobile glass manufacture and salvage, checking of wood in paint drying-ovens, cooperative labor plans, the group-bonus wage-incentive plan, tool design, tool maintenance, coining-press operations, reduction of waste, methods of shipping finished cars and reducing the cost of plant maintenance. Solicitation of other papers is being continued. The Meetings Committee encourages the immediate submission of volunteer contributions by members desiring places on the program.

Definite decision has been reached by the parent Society and the Detroit Section that an exhibition of production machines and equipment will not be staged coincidently with the 1924 Production Meeting. There is a possibility that such a production show will materialize in another year.

Maintenance

AS has been pointed out by George H. Pride, "maintenance" and "service efficiency" are synonymous. In the automotive industry, which in many respects is still in its formative stage, service should be regarded as business insurance, and the service personnel should be of a character that will assure the rendering of adequate service. This is sound doctrine, not excluding considerations involved in selfish, cold-blooded conduct of business. The inevitable result of haste is not infrequently the forgetting of essential things. It is clear, however, that those who give the best service, thus providing continuity of adequate use, will outclass all others in the long run. The customer must be kept satisfied during the life of the article he purchases.

A prime consideration is a definite and satisfactory service policy. As has been stated on behalf of a leading American automobile manufacturer, there is no such thing as "free service"; someone has to pay. The true meaning of service is, cheerful and efficient performance of some necessary task. The treatment of purchasers of cars should be uniformly fair, courteous and business-like, assistance being given in every reasonable way to keep the vehicles in good running-order. The purchasers should be told clearly just what they will receive without charge, such as inspection and adjustment service, not necessitated by neglect or abuse, at any time during a relatively short period after the time of the car purchase. In turn, the car owner should understand clearly what is not included in such service. It is the policy of the company referred to above, within 90 days after delivery of a new car, to install without labor charge any replacement parts it furnishes free of charge owing to their having been determined to be defective.

A new owner should be introduced to the man in charge of service in a given station, for it is this man who is responsible to the company for satisfying the customer. Obviously, a customer should not be promised what he will not receive. Likewise, he should be made to understand just what service will be rendered.

Preprints or Not?

ABOUT 2 years ago the practice of printing and distributing National meeting papers in advance of meetings was discontinued. Several factors were responsible. In the first place, it seemed a needless waste of the Society's funds to print and mail all papers to the members twice, once in the form of preprints and later in THE JOURNAL. It was reasoned at the time that the membership could be served more satisfactorily by printing as many papers as were available in the issue of THE JOURNAL published immediately after a meeting was held. Also, a fully illustrated news-account of the meeting and an abstract of the discussion can be published along with the complete papers. This practice is now in force.

Another factor that influenced the decision is the interference of preprinting with the prompt publication of THE JOURNAL. The same type and engravings are used for printing both THE JOURNAL and the preprints. Thus, while the preprints are in process, work on THE JOURNAL is practically at a standstill. To avoid holding-up the publication of THE JOURNAL, which, after all, is accepted as the full and authoritative medium of meetings reports, papers would have to be in and the job of preprinting completed weeks in advance of meeting dates. The latter condition would be an ideal one, but it has not been attainable in practice.

It is generally a difficult task to secure authors' manuscripts many weeks in advance of meetings. Frequently tests are under way on which the papers are to be based and these tests cannot be completed until shortly before meetings. Again, pressure of work at the office of the Society interferes with preprinting. Both of these conditions prevailed in various instances previous to the Summer Meeting in June. It is at times advisable for authors to revise their manuscripts after submitting them; for example, an author may wish to incorporate suggestions made by members of the Meetings Committee or his associates. It would be unwise for the Society to assume an arbitrary attitude toward authors with regard to the submission of papers far in advance of meetings. If this had been done during recent years, some of the most valuable papers would have been dropped from the program, thus depriving members of extremely valuable information at a time when it was most needed to combat a current problem. It has proved better judgment to cooperate with authors to the extent of allowing them to incorporate last-minute information in their papers.

Another element involved is the tendency of preprints to detract from interest in the presentation of papers. One may not listen attentively to a speaker when his complete paper has been available in printed form, either at the time of the meeting or in advance of it. Some busy men remain at their desks rather than attend meetings to listen to papers that they have had an opportunity to read in full. No comparative statistics are available to substantiate the opinion, but it is the belief of many connected with Meetings Committee work that

attendance at meetings and interest in the proceedings are materially increased when the papers to be presented thereat have not been widely circulated in advance.

The advantage of preprints as a means of promoting discussion at meetings is not lost sight of. A limited number of typewritten or galley-proof copies of many papers are available for mailing to men particularly qualified to offer prepared discussion of the subjects treated in the respective papers. Members desiring such copies of papers they are specially interested in can usually secure them upon request.

Patching Upholstery Leather

THE present S.A.E. Specifications for Upholstery Leather do not permit the use of patched hides. In the paper on Automobile Upholstery-Leather presented by K. L. Herrmann, of the Studebaker Corporation of America, at the 1924 Annual Meeting, the patching of grub-holes and other defects was recommended, it being stated that patching methods developed by the Subdivision on Upholstery Leather had resulted in a patch as strong and flexible as the hide and one that could not be detected from the finished side. Savings by the car builders of $400,000 per annum were considered to be attainable if the patching of hides should be generally adopted in practice.

Comments recently received from passenger-car builders indicate that patched hides are being used by several companies and that many more companies have the following of such practice under consideration. A general letter was sent to the upholstery-leather manufacturers by the Standards Department for the purpose of learning whether upholstery leather had been successfully patched in production. The information received indicated that in general the tanners do not wish to give out any information as to what they have accomplished. It seems that they are developing commercial methods of patching. Some of the comments received were:

> The problem of patching leather in such a manner as to permit automobile manufacturers to set a patch into a cushion, seat or back with full confidence that it will not develop trouble for them is so close to a solution by most of the large tanners that the Society of Automotive Engineers would be justified in revising its specifications on leather accordingly.
>
> It is possible to put on patches with a special adhesive "pyroxylin" mixture. We think that if this is done properly, the patch will not give any trouble in service. Of course, patches put in hides finished with linseed oil would show. The only finish upon which patching could be done successfully is what is commonly called "dope" finish. We believe that, if the patches are properly beveled and applied with the pyroxylin adhesive, manufacturers can be assured of proper wearing conditions and in this way save money by buying No. 2 selection hides. In the majority of cases the patch cannot be detected on the finished portion of the hide. So far as strength and durability are concerned, we feel the patches are practically equal to the other portions of the hide.

As all indications to date point to the correctness of Mr. Herrmann's statements, it is hoped that the tanners will be in a position in the near future to supply second-grade hides so patched that they will be entirely satisfactory for upholstery leather. It is regrettable that the tanners are not cooperatively working out a universal method of patching that could be generally adopted for automobile upholstery-leather. Without doubt, if the automobile manufacturers were faced with a similar problem, it would be solved by them in open discussion at technical sessions and meetings rather than by each manufacturer developing a method without regard to the work done and the results obtained by other manufacturers equally interested in furthering the interests of the industry.

Correcting Erroneous Impressions

TWO impressions that seem to be prevalent among the members relate to the presentation of papers at meetings of the Society and the publication of papers in THE JOURNAL. It is believed by many that meetings programs are arranged only by invitation. Others think that papers must be presented at a National or a Section meeting before they are eligible for publication in THE JOURNAL. Both impressions are erroneous.

One of the major reasons for scheduling National meetings of the Society many months in advance of their being held is to provide opportunity for members to make offers of papers for the programs. Most of the papers read before the Society are the result of solicitation at the direction of the Meetings Committee or the Council. However, this method is resorted to primarily because volunteer contributions are seldom forthcoming in sufficient number to complete the programs. Unfortunately, an apathetic attitude towards "speech-making" is maintained by a great many engineers and production men. So long as speech-making and participation in the legitimate and beneficial discussion of one's art are confused, procurement of papers by invitation must continue. This should not hinder those members who have a clear conception of their responsibility to scientific progress and wish to contribute ideas and experience in the form of papers. The Meetings Committee always welcomes the volunteering of good papers and wishes to encourage the practice.

Papers intended for presentation at National meetings should be submitted to the Meetings Committee at least 2 months before the meeting dates. Programs for National as well as for Section meetings must be planned well in advance. If a member waits until shortly before the time of a meeting to make known his wish, disappointment will frequently result. It is also important that prospective speakers select subjects that are strictly pertinent to the plans of the respective meetings. Other things being equal, papers which treat matters that are uppermost currently in the minds of automotive engineers are preferred.

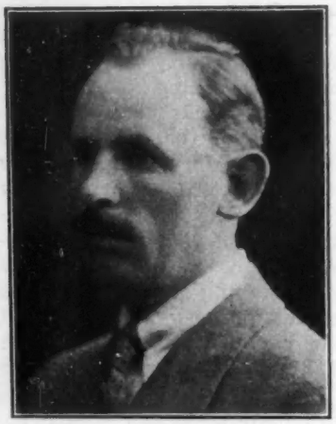
As to papers submitted for publication in THE JOURNAL without previous presentation at meetings, these are always desired and will be given careful consideration by the Publications Committee. In these cases also it is important that subjects of current interest be discussed. Comprehensiveness is not essential in such articles. In fact, the possibility of acceptance and prompt publication will be enhanced if the length of the article is limited to a concise presentation of the material in hand. This is natural in view of the heavy demand on THE JOURNAL'S text pages which exists at all times.

When a member has something of engineering interest and value to contribute to the art, he should feel that the pages of THE JOURNAL or a meeting of the Society provides the logical means for the dissemination of it. It may be a brief description of a new laboratory method or a novel production operation, the results of a research investigation, or simply an opinion on an outstanding problem. In no case should it be felt that volunteer submission of such material is not sought.

MEETINGS OF THE SOCIETY

AUTO TRANSPORT MEETING THIS MONTH

Papers Discuss Design, Operation and Maintenance of Buses, Trucks and Rail-Cars



JAMES PATERSON

Although design points will be considered to some extent during the sessions of the Automotive Transportation Meeting in New York City, Sept. 18 and 19, emphasis will be laid on the operation and maintenance of the motor-bus, motor truck and motor rail-car. This 2-day national meeting of the Society offers a most comprehensive group of papers by authorities of long experience in their respective fields. There is certain to be sufficient valuable material in the discussions and papers to more than repay those fleet operators, commercial-vehicle engineers, railroad equipment engineers and operators of public utilities who attend.

It will be our good fortune to have with us on this occasion one of England's foremost motor-transport authorities, James Paterson, managing director of Carter-Paterson, Ltd., operator of an extensive British motor-cartage service with headquarters in London. Mr. Paterson has taken a prominent part in the organization and administration of British motor-transport activities. He is a charter member of the Institute of Transport of Great Britain and a graduate of Oxford University. Carter-Paterson, Ltd., has developed operating methods, vehicles, bodies and trailers, the description of which should be of great value to American traffic men and engineers. Not only will Mr. Paterson set down his experience in the written paper, but he will show graphically the latest in British shipping methods by means of motion pictures.

MOTOR TRANSPORT IN COOPERATION WITH RAILROADS

One of this Country's most successful motor-cartage organizations will be represented on the program in the person of J. A. Hoffman, vice-president, Motor Haulage Co. of New York City. This company operates motor-transport facilities for several of New York's large shippers. Only recently the Motor Haulage Co. became associated with the Long Island Railroad in the handling of less-than-carload shipments in the Metropolitan area and along the railroad's lines leading out of New York City. In addition to Mr. Hoffman's paper, a visit will be made to the maintenance station and some of the operations of the Motor Haulage Co.

Types of trailer and semi-trailer for motor-cartage work

AUTOMOTIVE TRANSPORTATION MEETING

NEW YORK CITY — SEPT 18 AND 19

Thursday, Sept. 18

10:00 a. m. MOTORBUS SESSION (Hotel Pennsylvania)
V. E. Keenan, superintendent, bus division, United Electric Railways Co., Providence, R. I.
W. F. Evans, president, Detroit Motorbus Co., Detroit
J. B. Stewart, Jr., general superintendent, Youngstown Municipal Railway, Youngstown, Ohio

1:00 p. m. MOTORBUS LUNCHEON (Hotel Pennsylvania)

2:30 p. m. MOTORBUS SESSION (Hotel Pennsylvania)
F. D. Howell, vice-president, Motor Transit Co., Los Angeles
Hugh G. Bersie, engineer, Haskelite Mfg. Co., Chicago
R. E. Fielder, chief engineer, Fifth Avenue Coach Co., New York City

8:00 p. m. METROPOLITAN SECTION MEETING
Francis W. Davis, consulting engineer, Waltham, Mass.

Friday, Sept. 19

9:00 a. m. MOTORBUS INSPECTION TRIP
Buses will leave Society headquarters, 29 West 39th Street, at 9 o'clock, taking members and guests to maintenance shops of the Fifth Avenue Coach Co., the motor transport station of the Motor Haulage Co., and the fleet quarters of R. H. Macy & Co., one of New York's largest department stores. Return will be made to the Hotel Pennsylvania in time for the

1:00 p. m. MOTOR TRANSPORT LUNCHEON (Hotel Pennsylvania)

2:30 p. m. MOTOR TRANSPORT SESSION (Hotel Pennsylvania)
J. A. Hoffman, vice-president, Motor Haulage Co., New York City
H. W. Howard, transport engineer, General Motors Truck Co., Pontiac, Mich.
J. W. Cain, manager of purchases, American Short Line Railroad Association, Chicago

8:00 p. m. NEW YORK RAILROAD CLUB MEETING (Engineering Societies Building)
James Paterson, managing director, Carter-Paterson, Ltd., London, England
W. L. Bean, mechanical engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

Schedule of Sections Meetings

SEPTEMBER

10—DAYTON SECTION—Racing Equipment and Its Effect on Designing Better Cars—Fred Duesenberg
DETROIT SECTION—Outing, Dinner and Dance at Detroit Boat Club
14—BUFFALO SECTION—Automobile Competition Picnic
17—NEW ENGLAND SECTION (Boston)—Motorbus Lighting—A. C. Roy
18—METROPOLITAN SECTION—Should Motor Trucks Be Rebuilt Periodically or Replaced?—Francis W. Davis
19—CHICAGO SECTION—Inspection Tour of Yellow Cab Mfg. Co. Plant, followed by Golf Tournament in afternoon
22—CLEVELAND SECTION—
24—NEW ENGLAND SECTION (Worcester, Mass.)—Abrasives and Their Use
26—WASHINGTON SECTION—Chemical Control of Gaseous Detonation—Thomas Midgley, Jr.

OCTOBER

8—MILWAUKEE SECTION—Combined meeting with Chicago Section in Racine, Wis.
9—DETROIT SECTION—Roads—Governor Alex Grosbeck; Sidney D. Waldon
14—PENNSYLVANIA SECTION—The Traffic Problem—George Graham

will be described in a paper by H. W. Howard, tranportation engineer with the General Motors Corporation.

PAPERS ON GASOLINE-PROPELLED RAIL-CARS

While the gasoline-propelled rail-car is in the development stage it seems logical to effect a closer contact between the motive-power engineers of the railroad systems and the engineers in the automotive industry who are working on rail-car designs. This, in part, is the object of the papers on rail-car design and operation that will be given on the program of the Automotive Transportation Meeting. W. L. Bean, mechanical engineer of the New York, New Haven & Hartford Railroad, and J. W. Cain, manager of purchases of the American Short Line Railroad Association, will be the speakers on the rail-car topic. Mr. Bean is widely recognized as an authority on railroad motive-power engineering. He has been experimenting for several years with various types and sizes of rail-car, starting with the early trials of "motor trucks on rails." His latest experiments have been with rail-cars equipped with hydraulic transmissions. Since Mr. Cain acts for the short-line railroads in the purchase of rail-car equipment, he can state with accuracy the particular needs of this important group of rail-car users.

TWO SESSIONS DEVOTED TO THE MOTORBUS

The growth of motorbus transportation by leaps and bounds has naturally accentuated many problems of bus design, maintenance and operation. These are to be discussed thoroughly during the two motorbus sessions that are a part of the Automotive Transportation Meeting. One of the papers will be prepared by F. D. Howell, of the Motor Transit Co. of Los Angeles. This is one of the largest operating companies on the Pacific Coast, running 125 cars in local and through service over some 800 miles of highway, radiating out of Los Angeles in all directions.

R. E. Fielder, chief engineer of the Fifth Avenue Coach Co., will present a paper setting forth the methods followed by that company in maintaining its large fleet of local-traffic buses. Mr. Fielder's paper will be particularly significant since it will precede an inspection trip through the maintenance station where Fifth Avenue buses are given their periodic overhaul. Vincent E. Keenan, superintendent of the bus division of the United Electric Railways Co. of Providence, R. I., and J. B. Stewart, Jr., general superintendent of the Youngstown Municipal Railway Co., will indicate in their respective papers how motorbuses can be operated to advantage by electric street-railways. Other speakers on the motorbus include: W. F. Evans, president of the Detroit Motorbus Co.; and Hugh G. Bersie, engineer with the Haskelite Mfg. Co. Mr. Bersie will discuss some developments in body design that he believes to be desirable.

SHOULD TRUCKS BE REPLACED OR REBUILT?

Fitting in with the general program of the Automotive Transportation Meeting, the Metropolitan Section of the Society will hold its first meeting of the fall on Thursday evening, Sept. 18, and all in attendance at the National meeting will be invited to attend as guests of the Section. The paper will be given by Francis W. Davis, a specialist on engineering problems of commercial-vehicle operation. His paper will discuss continuous rebuilding and maintenance of motor trucks as opposed to the scheme of retiring them after they have operated a given number of years.

Several organizations have been asked to participate in the Transportation Meeting sessions. Among these are the New York Railroad Club, the American Electric Railway Association, the New York Traffic Club and the Society of Terminal Engineers. The meeting on Friday evening, Sept. 19, will be held under the auspices of the New York Railroad Club with the Society cooperating.

A schedule of the Automotive Transportation Meeting sessions with their locations is given on the facing page. The program has been arranged by a committee consisting of F. C. Horner, chairman, R. E. Plimpton and Charles O. Guernsey.

SECTIONS OPEN MEETING SEASON

Eight Attractive Programs Arranged for Month of September

September will be an active month among the Sections of the Society. As indicated in the calendar on this page, 8 of the Society's 12 outposts will hold meetings. Three of these will feature the social rather than the technical phase, this being considered one logical way to open the new season. Detroit Section will repeat its successful outing, dinner and dance of last September. This gathering will take place at the Detroit Boat Club on beautiful Belle Isle's shore on the evening of Sept. 10. On the same evening, the Dayton members will be listening to Fred Duesenberg, who needs no introduction, tell some of his interesting experiences in designing race cars, stressing particularly the value of the battle for speed supremacy to automotive development in general.

One of the most unique meetings ever held by a Section is that scheduled by the Buffalo group on the afternoon of Sept. 14. This is to be a combined picnic, reliability-run, gasoline-economy and hill-climbing contest to be participated in by members driving their own cars. At the end of the

(*Concluded on p.* 194)

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

COMMITTEES PUSH RESEARCH PROJECTS

Riding Qualities, Fuels and Highways among Major Research Problems

Many interested members of the Society lack the opportunity to maintain an intimate contact with the research activities of the Society. For this reason it is thought worthwhile to present in these columns from time to time brief reports of research activities and summaries of results accomplished. The Research Committee, H. L. Horning, chairman, and the Highways Committee, B. B. Bachman, chairman, in cooperation with the Research Department are actively engaged in promoting a number of projects that are reported briefly in this article. A period of 4 months, April to July, is included.

Riding Qualities

Improvement in the riding qualities of automobiles has for years attracted the interest of automotive engineers, but the importance of the subject is undoubtedly more fully realized now than ever before. As a major project of the Research Committee's program, the subject has been given full consideration with a view of assisting in establishing a rational basis for automobile design from the standpoint of comfortable riding.

During the period covered by this report, a bibliography of over 700 references, dealing with the many phases of the problem, has been practically completed. This work has involved a search of the technical literature published in this Country and abroad during the last decade. Many articles of especial interest have been abstracted. It is the intention to distribute copies of this compilation to interested members of the Society.

A paper on riding-qualities research, prepared by the Assistant Research Manager, was presented at the Summer Meeting of the Society. The object of the paper was to review the work that has already been accomplished by various investigators, to describe typical instruments and methods and to propose an outline of coordinated investigation. The paper above mentioned was published in the July issue of THE JOURNAL and is available in reprint form to interested members.

Considerable time has been devoted by the Research Department and committee members to conferences with experts in the industry and elsewhere who have studied the riding-qualities problem. Thus, contact has been established with those interested in both the mechanical and the human aspects, and much information of value has been obtained.

By correspondence an effort has been made to learn of investigations of riding qualities and studies of the effect of motions upon individuals as these questions may have been considered by steamship and railway companies.

Fuel Research

The cooperative fuel investigation, sponsored jointly by the Society, the American Petroleum Institute, the Bureau of Standards and the National Automobile Chamber of Commerce, has for some time been one of the major interests of the Research Committee. From the outset it has been the plan of the sponsors to establish the relation of fuel volatility to engine performance, not for a given year but for subsequent years as well. In other words, the immediate program has been considered as but a part of the broader, continuing project that has as its objective the securing and maintaining of a correct balance between the engine and the fuel. The present investigation has been based upon a general recognition of the fact that certain automotive equipment is in actual service and that certain automotive fuels are available. It has been the aim to determine the relative merits of these fuels for use in the existing equipment.

The results thus far obtained at the Bureau of Standards, where the greater part of the experimental work has been carried on, indicate that the increased dilution of crankcase oil is the outstanding consequence of lower fuel-volatility. During the period covered by this report, the investigation has dealt primarily with the factors contributing to crankcase-oil contamination and ease of starting, this being in accordance with the plans laid down by the Cooperative Fuel Research Committee at its meeting of May 16. At this meeting great satisfaction with the progress of the fuel investigation was expressed by representatives of both of the interested industries. They have since arranged through the American Petroleum Institute and the National Automobile Chamber of Commerce to continue their financial support.

It has been shown, in the more recent tests, that in the engines used the temperature of the jacket water has a marked influence upon the rate of dilution. This difference does not appear to be due to the change in the viscosity of the oil upon the cylinder-walls, or to a change in the piston-head temperature, but rather to the difference in the rate at which the diluent is added to or eliminated from the oil-films. It has been shown that under certain circumstances the diluent is eliminated at a fairly rapid rate and hence that an equilibrium condition may be reached, at which the rate of elimination balances the rate at which the diluent is added. Details concerning the experiments that have led to the above conclusions were presented at the recent Summer Meeting of the Society by J. O. Eisinger in a paper that appeared in the July issue of THE JOURNAL. Further measurements are being made of the effect of the rate of oil circulation upon the rate at which the diluent is eliminated from diluted oil. Engine tests in progress consist of comparisons of the rates of dilution at different engine-speeds. As the speed is increased, the duration of a given cycle is reduced; hence, the time during which the oil film on the cylinder-wall can become diluted by an individual charge is reduced. It is primarily to obtain information as to this particular factor that these tests at various speeds are being made.

As one step in the study of starting conditions, measurements are being made of pressures and temperatures in the engine cylinder. Tests have been conducted at various speeds and different throttle-positions in combination with changes in jacket-water temperature. Further tests will cover various engine conditions such as piston seal, valve leakage and the like. The purpose of these measurements is to obtain data as to conditions in the cylinder during the starting period.

Considerable time has been devoted to a study of a new method for determining the percentage of crankcase-oil dilution. It is hoped that this method may offer a simple and accurate means that can well be adopted as standard practice by investigators generally.

Fuel Specifications

What is the maximum allowable sulphur-content of a satisfactory automotive fuel? This is a question that the fuels

group of the Research Committee wishes to have answered from the standpoint of the manufacturers of vehicles and engines. Copies of the Federal Specifications for Fuels have been sent to prominent organizations of the industry with a request that views on this subject be presented. It is the intention to learn the attitude of the manufacturers on this and other phases of fuel specifications in order that the matter may be properly presented to those who formulate specifications.

Highway Research

Foremost among the activities of the Highways Committee is the investigation of truck impact now in progress under the auspices of the Bureau of Public Roads with the Society and the Rubber Association of America cooperating. As has been explained in these columns, this research has as its objective the determination of the effect upon the highway of trucks of various capacities, equipped with different types of tire. The information sought should be of great assistance in the design of highways and as an authoritative basis for legislation. Furthermore, it is hoped that load and stress data of value in truck design may be derived.

The tests are being conducted on a series of concrete test-slabs that have been laid at the Arlington, Va., Experimental Farms of the Bureau of Public Roads. For the purpose of establishing the actual conditions of impact on highways that should be reproduced on the test-slabs by the use of suitable obstructions, the trucks are being run over typical sections of road near the City of Washington. The existing impact-conditions are determined from accelerometer records taken from an instrument mounted upon the vehicles. Strain-gage and other observations are made during the runs over the test road.

During the April-July period, considerable attention has been devoted to the investigation and calibration of instruments suitable for the work in hand. Many preliminary runs have been made both upon the test-slabs and upon the open highway. Comparatively few conclusive data have been obtained, as it has been the policy to exercise extreme care in establishing the most suitable methods and choosing the most satisfactory instrument equipment before launching the extensive tests that are contemplated.

The Highways Committee has maintained close contact with the work and has assisted in formulating policies and in the general guidance of the project.

Other Projects

Truck-transportation costs, factors in tire design and air contamination by automobile-engine exhaust-gas are among the items, in addition to those above mentioned, that have been given especial consideration by the Research Committee and Department.

For some months, efforts have been made to collect reliable data relating to the cost of truck transportation as it is affected by the type and the condition of the highway. It has been found extremely difficult to obtain authoritative figures to show the differences in cost of tires, fuel, upkeep and depreciation as these factors are influenced by the differences in the highway. Many truck operators have been consulted and some material of interest has been procured. It is hoped that sufficient additional data may become available to justify the drawing of definite conclusions.

Interviews have been held with a number of experts in an attempt to establish the basic factors that determine the various features of tire design. It is believed that this work should be of assistance in the unification that is so greatly to be desired.

For many months the question of air contamination by automobile-engine exhaust-gases has been the subject of study. During the period covered by the present report, a number of interviews have been held with experts, and the details of the problem have been given careful consideration. A bibliography of publications concerning carbon monoxide and air contamination by automobile exhaust-gas has been compiled.

Department Activities

The Research Department of the Society has cooperated with the committees in the furtherance of the research projects. Other activities include the maintenance of a research information service for the members and the preparation of material for publication in The Journal.

Travel

The Assistant Manager of the Research Department has spent approximately one-quarter of his time in travel during the period covered by this report. His trips have been made in the interest of the committee work outlined above and have included visits to many members who are engaged in research work of interest to the Society. A number of technical gatherings and committee meetings have been attended.

Committee Meetings

Among the committee meetings attended by members of the Research and Highways Committees, the following may be mentioned:

April 10—Meeting of the Advisory Committee on Instruments for the Truck Impact Tests
April 18—Informal conference of sponsors for a Safety Code on Automobile Brakes and Brake Testing
May 16—Meeting of the Cooperative Fuel Research Committee and meeting of the fuels group of the Research Committee
June 25—Meeting of the Highways Committee
June 26—Meeting of the Research Committee
June 30—Meeting of the Highways Committee with the Bureau of Public Roads officials and the committee from the Rubber Association of America

All the meetings were held in the City of Washington, except those of June 25 and 26 which were held at Spring Lake, N. J., at the time of the Summer Meeting.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

PHYSICAL-PROPERTY CHARTS MUCH USED

Heat-Treatments as Well as Physical-Property Charts Are Extensively Used

In the last several months an extensive inquiry has been made of automobile and parts manufacturers as to the use of the Charts of Physical-Properties of Steels printed in Section D of the S.A.E. HANDBOOK. It had been recognized by the Iron and Steel Division that these charts were of considerable value to the manufacturer not equipped with metallurgical laboratories, but it was not actually known to what extent the charts served the industry.

Replies to the questionnaire sent out by the Standards Department were received from 122 manufacturers. This number included all but six of the automobile manufacturers responsible for 98 per cent of the total automobile production in this country.

Of the replies received, 114 manufacturers stated that they used the charts of physical-property data, as against 8 who stated that they did not use them. Ninety-five manufacturers stated that the charts were used for the guidance of the designing and the heat-treating departments. Sixty-seven manufacturers stated they were used for purchasing to physical specifications. In answer to the question whether forgings, stampings and parts machined from bar stock are purchased to chemical, physical or both chemical and physical specifications, 42 stated they purchased forgings to chemical specifications, 4 to physical specifications and 48 to both chemical and physical specifications; 38 stated they purchased stampings to chemical specifications, 12 to physical specifications and 29 to both chemical and physical specifications, and 35 stated they purchased parts machined from bar stock to chemical specifications, 9 to physical specifications and 60 to both chemical and physical specifications.

The fifth question was whether the Notes and Instructions on the Use of S.A.E. Standard Steel and the Heat-Treatment Data covered all needs without the inclusion of the physical-property charts. This might be considered as a corollary to the first question. Of the replies received, 19 stated that the Notes and Heat-Treatment Data did meet their needs without the inclusion of the charts; but 101 stated that the physical-property charts were needed.

The sixth question invited suggestions or constructive criticism in connection with the S.A.E. Notes, Instructions and Physical-Property Charts. The following comments and criticisms were received, and have been referred to the Iron and Steel Division for consideration:

COMMENTS SUBMITTED

The writer finds considerable use for the notes and charts, which are very complete. It might possibly be to the advantage of a great many engineers if some mark were used to show which particular specifications are usually carried in stock, as it frequently happens that a particular specification is required, only to find later that it is not carried in stock.

We think it would be well worthwhile to cover gray-iron castings, both chemically and physically.

The only suggestion we have to offer is that these notes and instructions be kept uptodate and that new materials be listed as soon as they are recognized commercially.

The only suggestion we have regarding these charts is that they be made more complete, covering additional steels that are not now covered by physical-property charts.

The notes and heat-treatment data seem to be very good so far as they go, but of late a number of special alloy-steels have been brought out, particularly for gears. I believe that the notes could be improved by giving information as to treatment of these new steels.

The work of the Iron and Steel Division has been most valuable in standardizing automotive steels. We consider the charts and general data, with reference to the heat-treatments and physical properties of the various steels, of great value, particularly in a case where one is taking up a steel for a different purpose or different kind of part than that with which he has previously had experience. We certainly recommend that all of this material be left in the hand-book.

We think it might be feasible to cut down the list of steels to some extent. We imagine that some numbers have been put in simply to make the range complete and represent steels that perhaps are hardly ever used. For our own purposes, for example, probably 9 or 10 steel specifications would cover everything. This, however, does not include tool steel.

The writer would suggest the elimination of the physical-property charts and the recommended heat-treatments, leaving only the chemical analysis for each specification and notes regarding the uses for which the steels are suitable. It is our experience that the charts have never been of any real practical use and that the suggested heat-treatments have done more harm than good. Anyone who does not understand the treatment of steel cannot use the recommended treatments successfully, and one who is familiar with heat-treatment does not need them.

I believe that the specifications are fairly complete as they stand, but would suggest including a specification for cast iron.

We suggest that more emphasis be laid on the fact that these charts cover the minimum elastic-limit and tensile-strength and the maximum elongation and reduction of area that may be expected from the types of steel shown.

We think it would be a very grave mistake to discontinue the physical-property charts, not so much on account of the larger companies that maintain their own metallurgical departments, but on account of the smaller companies that depend almost entirely on information obtained from the Society of Automotive Engineers and similar organizations and representatives of the steel companies for their guidance in the selection and treatment of steels.

I believe that additional physical-property charts covering the effect of size of section treated would be of value.

AUGUST DATA SHEETS ISSUED

Standards Approved at Spring Lake Included in New Issue for S.A.E. HANDBOOK

The August issue of data sheets for the S.A.E. HANDBOOK, mailed to the members during August, contained the Division recommendations submitted at the Summer Meet-

ing at Spring Lake and approved by letter-ballot of the voting members on July 24. The original reports were published on p. 625 of the June issue and the discussion thereon at the Standards Committee Meeting on p. 25 of the July issue of THE JOURNAL.

Although the August issue contains 36 sheets, the total number of sheets in the S.A.E. HANDBOOK remains the same, owing to the number of sheets cancelled. Members should remember to remove the cancelled sheets which are noted in the check-list that accompanied the data sheets.

The S.A.E. HANDBOOK, as revised, contains 572 pp. This is a larger number than one leather-binder can conveniently accommodate and consequently it has been found advisable by many members to divide the handbook into two parts, retaining Sections A to C inclusive in the old binder and putting the remaining sections in a new binder, both binders being marked to indicate the sections that they contain. In case members are not interested in certain classifications of standards, the respective sections can be removed from the handbook without destroying its general arrangement. In this way it is often possible for members interested in a limited range of automotive subjects to keep their S.A.E. HANDBOOKS down to a more convenient size.

SHOCK-ABSORBER MOUNTINGS

Opinion of Passenger-Car Makers Divided as to Need for Standardized Mountings

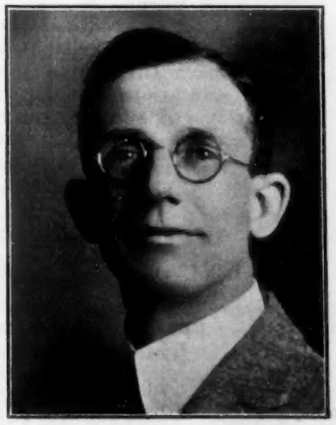
Although it was realized at the March meeting of the Parts and Fittings Division that standardization of shock-absorber mountings would be very difficult to accomplish, F. G. Whittington, of the Stewart-Warner Speedometer Corporation, was appointed a Committee of one to review the situation. At his request general letters were sent to the shock-absorber and passenger-car manufacturers to determine the consensus of opinion with respect to such standardization.

The results of the survey indicated that out of 50 passenger-car manufacturers, 35 use shock-absorbers as standard equipment; 38 provide holes so as to facilitate their mounting; 26 favor standardization of the mounting dimensions, and 18 do not favor such standardization. Letters received from 22 manufacturers of shock-absorbers indicate that 15 favor standardization and 7 do not. Complete information as to the result of these surveys was referred to Mr. Whittington and will form the basis of his report to the Parts and Fittings Division.

CHEAP SOCKETS CAUSE OF FAILURES

Use of 32-Volt Systems for Motor-Coaches Considered by Subdivision

A special meeting of the Subdivision on Bases, Sockets and Connectors was held in Cleveland on July 29 to consider the need for more substantial fittings for motor trucks and coaches. It was the consensus of opinion that failures in lamp fittings occurring at the present time are entirely due to the fact that the manufacturers have been using thinner metal than formerly as a result of demands from purchasers for cheaper products. It is consequently thought unnecessary to design larger fittings, the present designs, if properly made, being entirely satisfactory. It was decided to canvass the motor-coach and motor-truck builders to determine whether they would prefer to use the present standard fittings properly constructed; a larger type of fitting with the wires connected, but taking the standard lamp-base; or ¾-in. diameter fittings taking a ¾-in. diameter lamp-base. In order that the manufacturers may be able to judge which type of fitting would meet their requirements best, scale drawings and estimates of the cost of each type of fitting will accompany the general letter.



CHARLES E. GODLEY

Consideration was also given to voltage of electrical systems for motor-coaches and other gasoline-propelled vehicles having an electrical load of 500 watts or over. The use of the 32-volt system was suggested although it was recognized this would result in greater lamp-filament breakage, increased battery-weight and cost and difficulty in regulating the voltage. To give the subject more detailed consideration, a Subcommittee, consisting of R. N. Falge, chairman, W. H. Hutchins, E. C. Reinhart and A. J. Scaife, was appointed. The Subcommittee reported later in the day that it was considered desirable to determine the opinion of the builders of motor-coaches and trucks as to whether the present standard 6 to 8-volt or 12 to 16-volt system should be adopted as standard practice for the electrical systems of motor-coaches and heavy-duty motor-trucks or whether a new standard of 32 volts should be considered. A general letter has been sent out by the Standards Department and the comments received will serve as a basis for the Subcommittee report.

Those present at the Subdivision meeting, which was held at the Old Colony Club in the Hotel Cleveland, were Chairman C. E. Godley, of Edmunds & Jones Corporation; E. A. Anderson, of the Bryan Marsh Lamp Co.; W. B. Churches, of the White Motor Co.; D. S. Cole, of the Leece-Neville Co.; R. N. Falge, of the National Lamp Works; W. H. Hutchins, of the North East Electric Co.; B. M. Leece, of the Leece-Neville Co.; G. G. Meade, of the Chicago Electric Mfg. Co.; C. A. Michel, of the Guide Motor Lamp Mfg. Co.; W. E. Menzies, of the Westinghouse Electric & Mfg. Co.; F. H. Prescott, of the Remy Electric Co.; E. C. Reinhart, of the J. G. Brill Co; A. J. Scaife, of the White Motor Co.; Earl Turner, of the Automotive Electric Association; T. Vander Wall, of the C. M. Wall Lang Co.; T. I. Walker, of the Providence Base Works, and R. S. Burnett, manager of the Standards Department of the Society of Automotive Engineers.

NEW METHOD OF GAGING NUT SLOTS

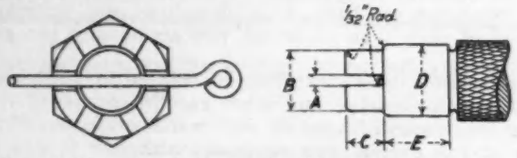
Practice Proposed Permits Maximum Variation of Slot in Nut and Hole in Screw

A method of gaging the position of slots in castle nuts has been submitted to the Screw-Threads Division by E. H. Ehrman, for consideration as S.A.E. Recommended Practice. The method is given in the accompanying illustration and table. It permits as much variation in the location of the cotter-pin hole in the screw as it does in the location of the cotter-pin slot in the castle nut.

It is recognized that some approximations must be made in the application of this gaging method, chiefly due to variations in the bore of the nut, arising partly from the variations in the drilled hole and partly from the additional change in the bore due to tapping. These errors, however can be reduced somewhat if the nut manufacturer bases the diameter of the plug on the minimum drilled-hole; and if the user bases the diameter of the plug on the minimum minor-diameter of the threaded hole.

The diameter of the gaging pin is intended to be the mean of the width of the slot in the gage and the diameter of the cotter-pin; the drill-rod size nearest this dimension, but larger, being used. The diameter of the slotted part of the gage plug is made smaller so as to clear the burrs occurring in blanking and slotting the nut.

It is expected that the method of gaging proposed will be tried out by several manufacturers represented on the Screw-Threads Division before it is finally submitted to the Standards Committee. Statements of the experience of any Society members relative to this or equivalent methods of gaging will be appreciated by the members of the Screw-Threads Division and will be referred to them if sent to the S.A.E. Standards Department.



The drill rod shall preferably be tempered and should fit in the slot of the gage without shake.

Nut	Slot Width[1]	Cotter Pin Diameter[2]	Drill Rod		A	B	C	D[1]	E
			No.	In.					
¼	5/64	1/16	49	0.072	0.072	0.182	5/32	0.2113	¼
5/16	5/64	1/16	49	0.072	0.072	15/64	5/32	0.2674	19/64
3/8	1/8	3/32	34	0.110	0.110	19/64	3/16	0.3299	11/32
7/16	1/8	3/32	34	0.110	0.110	11/32	3/16	0.3834	25/64
½	1/8	3/32	34	0.110	0.110	13/32	¼	0.4459	7/16

[1] Minimum minor diameter for free fit (Class 2) nuts, p. C[1]j of the S. A. E. Handbook. If the nuts are not threaded in accordance with the American Standard for Screw Threads, the diameter shall be the same as the diameter of the go plug gage for the bore.
[2] S. A. E. Standard dimensions, p. C2 of the S. A. E. Handbook.

ARMY AND NAVY CONFERENCE HELD

E. W. Rounds Represents Aeronautic Division at Conference of Air Services

At the request of the Bureau of Aeronautics of the Navy Department, President Crane appointed E. W. Rounds, of the Wright Aeronautical Corporation, and W. L. Gilmore, of the Curtiss Aeroplane & Motor Co., Inc., to represent the Aeronautic Division at the first joint Army Air Service-Navy Conference on the standardization of requirements and specifications for aircraft standard parts, held at the Naval Aircraft Factory in Philadelphia from June 28 to July 28, inclusive. Mr. Gilmore was unable to attend the conference, but was represented by F. R. Weymouth and J. A. Williams.

In transmitting the minutes of the conference to those interested, Lieut. R. S. Barnaby stated that

> Considering the many subjects under discussion and the differences and obstacles to standardization which have grown out of years of usage, it is believed that considerable progress was made. It is believed that this is in a great measure due to the cooperation given by the representatives of the Society of Automotive Engineers and the various manufacturers who gave considerable time to this work.

The following is quoted from the minutes of the conference:

> The purpose of the conference was to eliminate the differences in the specifications and requirements for the standard parts of the Army Air Service and the Navy and to adopt a uniform system of standards. This will permit the manufacturer of standard parts and the manufacturers of aircraft to carry only one set of such material, which they may use to fill both Army and Navy orders. It will also permit an interchange of parts between the two services.
>
> The Conference has taken steps to cut down the number of kinds and sizes of standard parts and to make such changes in the parts adopted as have been shown in service to be desirable and has endeavored at the same time to change the existing standards as little as possible. The parts upon which action was taken are:

Aircraft Bolts	Universal Strap-Terminals
Aircraft Nuts	Rigid Terminals
Clevis-Pins	Turnbuckles
Cotter-Pins	Thimbles
Streamline Tie-Rods	Wood Washers
Hose Liners	Control Pulleys

> Drawings showing the new joint standards will be prepared by the Naval Aircraft Factory in accordance with the decisions of the conference. These drawings will be known as "Army-Navy" or "AN" Standards, and will have a new series of numbers beginning with number one and preceded by the letters AN. An AN Standard, adopted in accordance with the above procedure, may be changed by agreement at a subsequent Conference only.
>
> It is not the intention of the Conference to have the new AN Standards render obsolete immediately the existing standards. In practically all cases the old and the new are interchangeable, or the old may be readily converted to the new by minor modification. Where it is impracticable to make the conversion, the Army and Navy will accept the old standards until the supply on hand is exhausted. Manufacturers of standard parts will receive waivers on orders calling for the new standards so that they may deliver material conforming to the old standards where it is shown that the material was manufactured before the promulgation of the AN Standards. It is desired, however, that new parts, made after such promulgation, be in accordance with the AN Standards.

It is anticipated that the result of this and future conferences will have an important bearing on the work of the Aeronautic Division of the Society.

COACH SPECIFICATIONS CRITICIZED

Survey of Single-Deck Motor-Coach Practice Made for Motor-Coach Committee

The Board of Public Utility Commissioners of the State of New Jersey has had under consideration for some time tentative specifications for motor-coaches intended for operation in the various municipalities of that State. The hearings of the Board on this subject have been open to all those interested. It was desired to have the cooperation of engineers and traffic supervisors. The last conference on the standardization of motor-coaches was held on May 28 in Newark.

The Society is planning to proceed with engineering standardization relating to motor-coaches as soon as their design becomes more stabilized, it being felt that motor-coach engineering is now in a state of transition. The Motor-Coach Committee was appointed in November, 1923, by the Council with the intention that it would serve as a steering committee until it is found desirable to appoint a Motor-Coach Division of the Standards Committee.

The specifications tentatively approved by the Board of Utility Commissioners as a result of the last conference were sent to the manufacturers of motor-coaches in order that the Board might have the benefit of their comments. A copy of the more important specifications tentatively approved by the New Jersey Board follows, together with constructive comments submitted by motor-coach manufacturers.

Tentative Motor-Coach Specifications

Body Specifications.—The maximum overall-length of body shall be 21 ft. and the minimum length shall be 16 ft. The maximum outside-width shall be 94 in. and the minimum 84 in. The maximum inside-height from floor to ceiling shall be 78 in. and the minimum 76 in.

Window-Guards.—All coaches must be equipped

with window-guards with at least three rails spaced 2 in. apart; the minimum height to be 8 in. If screens are used, their minimum height shall be 8 in.

Inside Lamps.—Six dome-lamps and one step-lamp shall be used for 16-ft. bodies; the bulbs shall be not less than 15 cp. For 18-ft. bodies, not less than eight dome-lamps and one step-lamp shall be used. For 20 to 21-ft. bodies, not less than 10 dome-lamps and 1 step-lamp shall be used.

Heating System.—A suitable heating-system, which shall be approved by the municipalities, shall be used.

Gasoline Tanks.—No coach shall be operated with the gasoline tank located inside of the body.

Guard-Rail.—All coaches shall be equipped with a suitable guard-rail to prevent passengers from obstructing the view of the driver.

Partition.—A partition constructed of wood and glass shall be located behind the driver's seat.

Ventilators.—All coaches shall be equipped with at least four ventilators of a type satisfactory to the municipalities, subject to approval by the Board of Public Utility Commissioners.

Floor-Boards.—The front floor-board shall be constructed of steel, or, if of wood, protected by fireproofing material.

Seating Arrangement.—The seating arrangement shall be left to the municipalities, subject to approval by the Board of Public Utility Commissioners.

Width of Door.—There shall be a clearance of 24 in. in the entrance and exit doors.

Chassis Length.—The chassis should be the full length of the body and should extend to the body sills.

Bumper.—The bumper shall extend 4 in. beyond the body limits and shall be attached to the chassis.

Push-Buttons.—All coaches must be equipped with push-buttons located between the windows.

Stop-Lights.—All coaches must be equipped with a stop-light.

Tires.—No coach shall be operated with solid rubber tires.

Height of Chassis Frame.—The maximum height shall be 32 in. from the ground to the top of chassis frame.

Comments of Motor-Coach Builders

A maximum length of 22 ft. should be adopted for interurban or deluxe buses. This length will allow space for 25 passengers and for the increased size of seats that is necessary for long rides. It will also allow ample leg-room.

The New Jersey State Law for motor vehicles specifies a width of 96 in. Therefore, why should the width be made 94 in.? The maximum vehicle-length of 28 ft. specified by law should take care of the body length. Regarding the height from the floor to ceiling, the body builder's standard of 75 in. should be adopted. No maximum need be mentioned.

In the case of the motor-coach, the back of the body is an ideal place for the tire carrier, a practice almost universal in the passenger-car field. The inside of the body is not suitable for the tire carrier. The side of the body is not a permissible location because of the necessity of utilizing every inch of space available for the body, to obtain a good turning-radius and to provide for sufficient visibility. When carried under the body, the tire carrier does not permit sufficient ground-clearance with the new low-type bodies coming into use. It exposes the tire and the wheel to dust and mud. When carried on the back, a really protective bumper can be fitted and so designed, as on street-cars, to prevent back riders.

It is inadvisable to restrict the body length to 21 ft. Many bodies are in safe and satisfactory use today having a length in excess of 21 ft. Many future developments may bear upon this question. Assuming that a maximum overall body-length of 21 ft. were adopted, practically all double-deck coaches would be ruled out, assuming the platform length is taken into account.

It is inadvisable to restrict the body length to a minimum of 16 ft. In many instances special bodies may be required having a limited seating-capacity that would bring them under this dimension.

The minimum width should not be restricted to 7 ft. Many special bodies are built, the width of which is less than 7 ft., particularly bodies of the limousine or sedan type.

It is also inadvisable to limit the height, particularly since the requirements of city-service, parlor-car and limousine or sedan types of body differ materially, the average heights of which are about 6 ft. 2 in., 5 ft. 10 in. and 4 ft. 8 in. respectively.

Equipping all coaches with window-guards would be open to question. Certainly no necessity for window-guards with windows which drop exists since their normal projection from their pockets provides an adequate safety-factor.

The heating requirements would be covered by merely requiring a certain temperature during certain months of the year, the same as is specified for other common-carriers. The type of heating system is immaterial and should not be left to any political subdivision of the State for approval.

To restrict the gasoline-tank location to the outside of the body would be unwise, for thousands of coaches are in safe and satisfactory operation with gasoline tanks inside. On double-deck coaches a very satisfactory location is under the driver's seat. On parlor-car and sedan or limousine types, tanks may be arranged under the seat of the driver or of the last passenger. The trend today is toward lowering the chassis height and accordingly locating the tank alongside or under the frame presents many difficulties. Tanks so located are dangerously close to the ground and the likelihood is much greater of fires occurring due to the tank becoming damaged and fuel finding its way onto road than as a result of fires inside the body.

From an operating standpoint, the main thing to strive for is simplicity; gravity feed in this respect is ideal. Assuming, however, that the tank must be outside of body, the vacuum system must be employed with its complications, hazards, annoyances and inconveniences.

The proposed regulation covering the floor-boards is too loosely worded. The kind of material should not be mentioned. It should say that "the front floor-boards shall be made fireproof," with the addition of a penalty in a case of fire, as a preventive measure.

In many cases a partition behind the driver is undesirable because of the added weight, noise and maintenance, and is not necessary if a proper guard-rail is provided to keep the passengers from crowding the driver.

While various reasons for having a partition back of the driver can be advanced, it is also a possible source of danger to passengers. Should the coach make a sudden stop, anyone standing near the partition might be thrown against it and cut by broken glass. A partition of this kind on coaches operated on the "pay-as-you-enter" system would have to be opened on the driver's side at least and would largely lose its usefulness.

Three ventilators of modern and standard types offered today are sufficient to ventilate a body 22 ft. long carrying from 20 to 30 passengers. Considerable experimental work is being done on ventilators at present and it would be premature to standardize ventilators, except to insist that the ventilation shall be ample.

The number of ventilators is not directly related to the amount of ventilation obtained. A simply worded

regulation based upon the minimum amount of air changed per minute would be more effective, and would permit a wide variety of ventilation systems to be used until such time as it shall be advisable to be more specific.

It would be impracticable to have bumpers extend 4 in. beyond the body limits. The wording of this clause is not entirely clear. Our assumption is that the proposed overall-width of bumper would be 8 in. greater than the overall-width of the body at the widest point, namely over the fenders. A restriction such as this would necessarily add to traffic congestion and the possibility of accidents would be considerable since children could readily seat themselves on the ends of the rear bumpers.

The arbitrary elimination of solid tires is unwise. No doubt as the automotive industry develops, great improvement will be made in both spring-suspensions and tires. Unquestionably, considerable attention will be paid to the general matter of riding performance and it is our impression that the use of solid and cushion tires in some form will increase rather than diminish. Many operators will find that the cost of pneumatic tires is no small proportion of their total costs, and as a result pressure will be applied to manufacturers to carry out improvements in suspensions generally.

It is recommended that the maximum height from the ground to the body floor, at the entrance door of 30 in., with 32-in. tires, be adopted. This specification should be flexible because natural competition between manufacturers will bring about a proper height.

At a meeting of the Motor-Coach Committee held in March with the Equipment Sub-Committee of the American Electric Railway Association, it was decided that the Standards Department should make a survey of present practice with respect to certain controlling dimensions. The data given in the accompanying table were tabulated from information submitted as a result of the questionnaire sent to the motor-coach and body makers.

FLEXIBLE-DISC STANDARD NEEDED

Survey of Present Practice Indicates 48 Different Sizes in Use by 54 Companies

At the time the present S.A.E. Recommended Practice for Propeller-Shaft Flexible-Discs was approved by the Parts and Fittings Division it was decided to extend the standard to include flexible-discs intended for generator, magneto and distributor drives. Information was obtained from engine makers and automobile makers building their own engines as to the dimensions of such flexible-discs used. The results of this survey were tabulated and referred to the Division to serve as a basis for determining what sizes should be adopted as standard.

VARIATION IN SIZES OF 3-IN. FLEXIBLE-DISCS

Thickness, In.	Inside Diameter, In.	Bolt-Circle Diameter, In.	Bolt-Hole Diameter, In.	Application
1/4	13/16	2 1/8	5/16	Generator
1/4	7/8	2 5/16	17/64	Magneto and Generator
1/4	1	2 1/4	1/4	Magneto and Pump
1/4	1	2 3/8	1/4	Generator and Magneto
1/4	1	2 1/4	17/64	.....
1/4	1	2 1/4	1/4	Generator
1/4	1	2 1/4	5/16	Generator and Magneto
1/4	1 1/8	2 1/4	1/4	Generator
1/4	1 3/16	2 1/4	1/4	Magneto
1/4	1 1/4	2 1/4	17/64	Generator
1/4	1 3/8	2 1/4	1/4	Generator
9/32	1 1/8	2 1/4	1/4	Generator
5/16	1 1/4	2 1/4	1/4	Generator

As an indication of the small variations in practice, the accompanying table lists the flexible-discs, having a 3-in. outside diameter, which were reported. It will be appreciated that the manufacturers using this size of disc could easily change to a standard size if it were available and that this action would greatly benefit the disc manufacturers and result in their savings being passed on to the engine and car manufacturers. Servicing of cars using standard sizes would also be greatly facilitated.

SUMMARY OF DATA SUBMITTED ON SINGLE-DECK MOTOR-COACH PRACTICE

COMPANY	DOORWAY		Body Overall Width, In.	Minimum Height, Floor to Roof, In.	Tread, Center-to-Center of Tires, In.		EMERGENCY DOOR			Dash to Center of Rear Axle, In.	Floor Height, In.
	Width, In.	Folds "In" or "Out"			Front	Rear	Location	Height, In.	Width, In.		
Bender Body Co.	31	In	90	72	....	....	Left Rear	68	27	157 and up	32
Federal Motor Truck Co.	30	In	90	75	60	64 7/8	Left Rear	72	32	158	36
Commerce Truck Co.	32 1/4	....	70	49 3/8	56	60	Left Side	47 5/8	32 1/4	153	26 1/2
	32 1/4	....	70	49 3/8	58	58 & 62	Left Side	47 5/8	32 1/4	163	30
Garford Motor Truck Co.	29	In	86	74	56	65	Left Rear	61 1/4	27	154	31
	30	In	87	75	68	75 3/4	Left Rear	61	25	157	28 1/2
International Motor Co.	27 5/8	In	88	73 1/2	68	63 3/8	Left Rear	27 3/8	57 3/8	163 15/16	24 11/16
	30 5/8	Out	80 7/8	56 3/8	68	63 3/8	5 Doors	....	....	186 1/8	28 11/16
	30 5/8	Out	80 7/8	56 3/8	68	63 3/8	8 Doors	....	....	186 1/8	28 11/16
Jackson Specialty Body Works	30	Out	80	54	56	56	.....	....	....	152	3
Kimball Motors Corporation	30	In	88	76	58 1/2	58 1/2	Rear	64	30	142	18
	30	In	88	76	58 1/2	58 1/2	Rear	64	30	190	18
G. C. Kuhlman Car Co.	29	Out	90	75	....	....	Left Rear	60	25	137	27
	29	Out	90	75	....	....	Left Rear	60	25	157[a]	27
	29	Out	90	75	....	....	Left Rear	60	25	167[a], 180 3/4	27
Menominee Motor Truck Co.	28	Out	71 1/2	53 1/2	56	57 3/4	.....	....	....	151	26 1/2
	28	Out	71 1/2	53 1/2	64	66	.....	....	....	194	26 1/2
	28	In	84	75	68	73	Left Rear	....	....	156	28
	28	In	84	75	68	73	Left Rear	....	....	190	28
Moreland Motor Truck Co.	30	In	71	72	56	56	Left Rear	53 1/2	18	152	22 1/2
	30	In	87	74	59 9/16	60	Left Rear	54 3/8	18	152	24
	30	In	87	74	69	70	Left Rear	54 3/8	18	164 1/4	24
Standard Motor Truck Co.	24	Out	84	78	56	66	Left Rear	72	24	96	30
White Motor Co.	31	Out	84	54	58 19/32	65 1/2	Left Rear	60	31	157	29
	31	In	90	75 1/2	58 19/32	65 1/2	Left Rear	73	31	157	31
Yellow Coach Mfg. Co.	28 3/16	In	89 3/4	76	72 1/4	76 3/4	Left Side	54 1/2	31 3/8	171 1/4	26

[a] Includes approximately 7 in. for cowl.

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Outstanding Tendencies in Axle Design

By Willard F. Rockwell[1]

Mid-West Section Paper *Illustrated with* Drawings

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

TENDENCIES of the industry toward lower costs have been reflected in axle design. Large-volume business has made it worthwhile to introduce changes in the design of passenger-car and light-truck axles to increase production economy and improve design. For heavy trucks, the trend has been to keep costs down by making no changes that would involve added expense for tools, jigs, dies and fixtures. Front-wheel brakes for passenger cars have resulted in changing front-axle I-beam sections and front-spring design to take care of the increased stresses such brakes introduce.

In the design of rear axles for passenger cars, no fundamental change has occurred, although the change from the full-floating and three-quarter floating types to the semi-floating axle and a change in mounting the bevel pinion are two features that seem to be coming to the fore. As to the latter, the overhanging pinion formerly predominated; but many manufacturers have changed and some will change this year to a straddle mounting.

Mr. Rockwell expects the introduction of worm-drive passenger-car axles within the coming year. Over a period of several years, the bevel-gear axle has steadily increased in favor for a motor-truck rear-axle, due to low cost and efficiency for light trucks. A 5-ton truck recently brought from Europe has a bevel-gear axle and is equipped with solid tires. A straight-tooth bevel gear is used with a 7-tooth pinion and a 56-tooth ring-gear; this gives only an 8 to 1 reduction, whereas most 5-ton trucks in this Country require at least a 10 to 1 reduction.

For 6 years, the worm-drive truck-axle has been more popular than all other types; for any given reduction, it is possible to obtain a suitable gear-center, a favorable lead-angle and a low tooth-pressure, which will give high efficiency at normal operating speed. The worm-drive has a mechanical efficiency none too high, but it has justified its existence. The declining popularity of the internal-gear drive may be due to its increased price; the chain drive probably will remain in the field, as some prefer it to all other types.

All axle manufacturers are trying to reduce unsprung weight. The double-reduction axle unquestionably has shown the greatest increase in popularity under heavy-duty vehicles. In the spur and bevel type, it is possible to select spur and bevel pinions that have a sufficiently large number of teeth for high efficiency, together with a heavy pitch and satisfactory cross-sections for the ring-gears to hold distortion by heat-treatment within reasonable limits. Its efficiency is high throughout the working range, and changes in ratios can be made quickly without serious effect on the various components. This type of axle was chosen by leading English experts for the heavy-duty British subsidy war trucks.

Future axle-design will be influenced by balloon tires, with a consequent reduction of the brake-drum diameters; by greater reductions and more steps in transmissions; by desires for greater road clearance and body clearance, and more satisfactory brakes and possibly by the use of three or more axles, two or more being driving axles, to obtain greater safety, better load-distribution and better traction with less damage to roadbeds. Balloon tires may force the use of axles that provide a wider car-tread.

To date, transmissions have been designed to operate approximately 5 per cent of the time a truck is in service; additional requirements in this respect will necessitate changes in design. The interest in transmissions leads Mr. Rockwell to believe that the two-speed rear-axle will be demanded very soon. An axle for railroad use that is arranged for four-wheel drive provides gear positions for idling and reverse driving and permits the use of all transmission speeds in either direction of travel.

IN the automotive industry, the outstanding tendency has been toward lower costs. This is reflected in axle design. The automotive industry as a whole and the parts makers in particular have plunged into the keenest competition. In the design of passenger-car axles and light-truck axles, the large volume of business has made it worth while to introduce changes that will increase economy in production as well as improve the design. In the heavy-truck field, the general tendency has been to keep costs down by making no changes that involve additional expense for tools, dies, jigs and fixtures. Front-wheel brakes for passenger cars seem to have been adopted with a rush. It is too early to foretell the final result. Some manufacturers adopted brakes of this type before perfecting them, while others condemned the type too hastily.

The front-wheel brake has resulted in changing front-axle I-beam sections and front-spring design to take care of the increased stresses. It also has caused a large number of manufacturers to change from the Elliott to the reversed-Elliott type of axle. Without front-wheel brakes, the Elliott type probably is somewhat lower in cost of manufacture; but, if the internal type of front-wheel brake is used, the reversed-Elliott type has a number of advantages which make its use more convenient.

While it is always desirable to have the tire contact with the road as nearly as possible in line with the projection of the axis of the king-pin, to promote easy steering, it is essential that this condition be approximated to have safe steering with front-wheel brakes.

Semi-Floating Type of Axle

In the design of rear axles for passenger cars, no fundamental change has taken place, although two fea-

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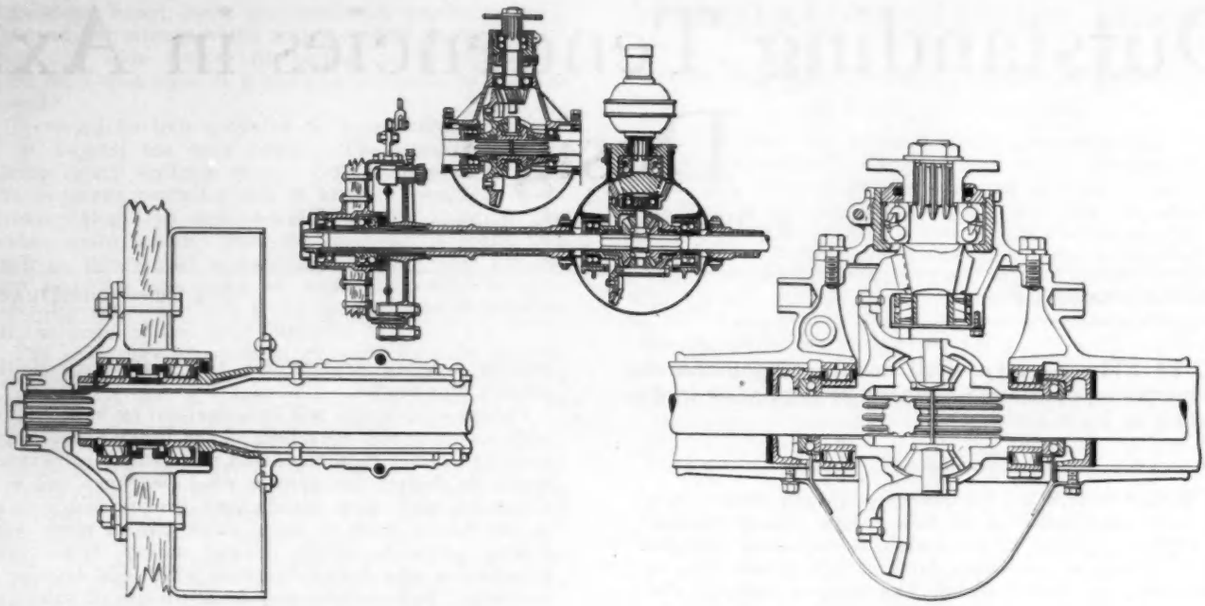

FIG. 1—MINOR CHANGE IN PASSENGER-CAR REAR-AXLE DESIGN
Formerly, the Overhanging Pinion Predominated, but Now a Large Number of Manufacturers Have Changed To Use the Straddle Mounting and Some Others Intend To Change This Year

tures seem to be coming to the fore. First is the change from the full-floating and the three-quarter-floating types to the semi-floating type of axle, made by several of the largest manufacturers and contemplated by others. The semi-floating design is somewhat lower in cost, and the distribution of the bearing loads is superior from an engineering standpoint. The chassis engineer sometimes changes treads and wheel-centers without regard to the axle-bearing layout; in a semi-floating design, offsetting the wheel-center 1 in. or more does not affect the bearing loads as greatly as it does in either the three-quarter-floating or the full-floating types. For example, with a standard wheel and full-floating construction with two wheel-bearings of the same size, it is customary to figure on carrying the wheel-center directly between the bearings. If the wheel-center is moved over 1 in., this balance is thrown out so that one bearing-load is greatly increased, while the other does not carry its share of the load.

The second minor change in rear-axle design for passenger cars relates to the mounting of the bevel pinion. This is shown in Fig. 1. Formerly, the overhanging pinion predominated, but now a large number of manufacturers have changed to use the straddle mounting, and some others intend to change this year. In the straddle mounting, the loads on the bearings are distributed somewhat better so that smaller bearings can be used, but the question always arises whether the trunnion bearing can be made sufficiently large and whether it can be supported rigidly, inasmuch as it cannot be supported from four sides. The straddle mounting limits the available gear-ratios for any one design. In this connection, we expect to see the straddle mounting dominate with the double-row ball-bearing or double taper-bearing on the front, completely controlling the gear adjustment, and a straight roller-bearing or ball-bearing floating at the rear or trunnion position. In the light-truck field, the straddle mounting is strictly limited to axles in which the range of ratios is not very great. A failure of one of the parts in the differential or bevel-gear assembly doubtless will result in more damage in the case of the straddle mounting, but the lubri-

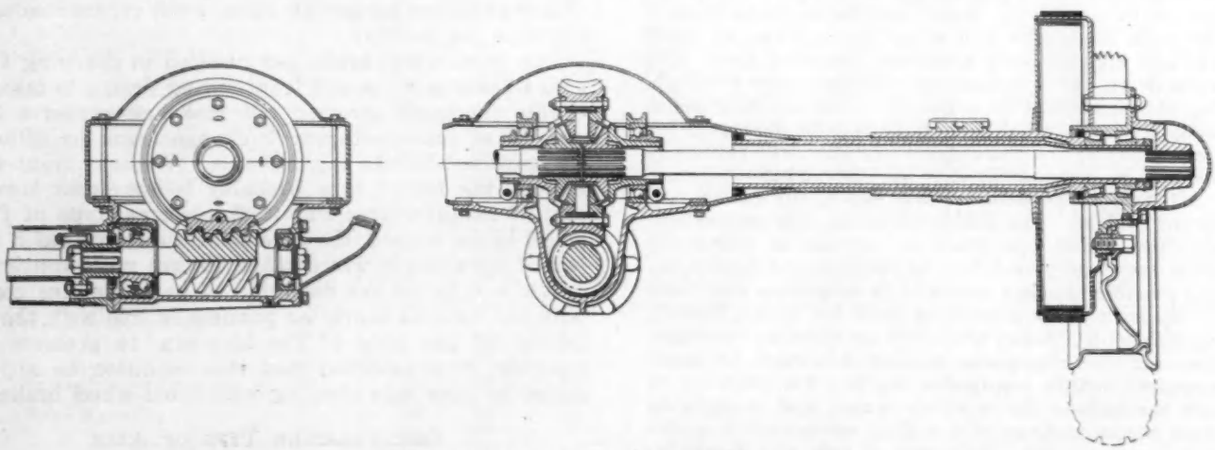

FIG. 2—WORM-DRIVE FOR PASSENGER-CAR AXLES
Worm-Driven Axles Are Expected on the Higher-Priced Closed Passenger-Cars within the Coming Year. They Are Slightly Less Efficient Mechanically and Cost More than Bevel-Gear Axles but Their Permanent Quietness Is Desirable. The Development of Accurate Grinding-Machines for Finishing the Steel Worms Has Increased the Efficiency and the Life of the Gears

cation of the pinion bearings should be much easier with that type.

Worm-Drive Passenger-Car Axles

We expect to see within the coming year the introduction of worm-drive passenger-car axles. One of the foremost passenger-car engineers in this Country has designed such an axle and several builders of high-priced cars are experimenting with them. Worm-drive axles are slightly less efficient mechanically and they cost more than bevel-gear axles, but their permanent quietness eventually will bring them into use on passenger cars. The development of accurate grinding-machines for finishing the steel worms has increased both the efficiency and the life of the gears. European engineers have used worm-gear passenger-car axles for many years, and the difficulty of securing bevel-gear axles that are quiet on the initial test and remain quiet during the reasonable life of the car undoubtedly will bring about the use of the worm gear under the higher-priced closed passenger-cars. This type is shown in Fig. 2.

Motor-Truck Rear-Axle Types

Fig. 3 shows the changes in motor-truck rear-axle types over a period of several years. The chart is based on the number of models offered by all known builders; while it is not based on total truck production, it does bear a relation to the actual production.

The bevel-gear axle showed a decline in 1 year but, since then, it has been rising steadily owing to its low cost and consequent return to favor under light trucks. It is very efficient for certain ratios but, so far, in American practice, it has been limited strictly to use

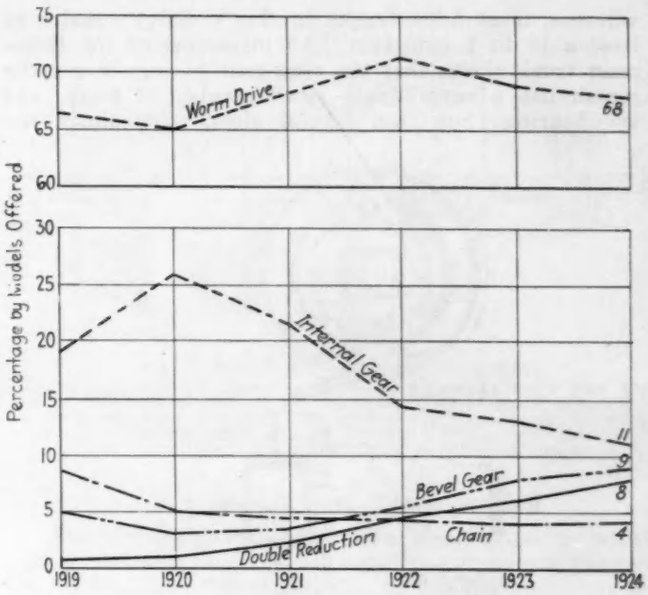

Fig. 3—Changes in Rear-Axle Types

The Chart Is Based on the Number of Models Offered by All Known Motor-Truck Builders Over a Period of Several Years. While Not Based on the Total Truck Production, It Does Bear a Relation to the Actual Production

tween the gears only takes place directly on the pitch-line. As the tooth contact recedes from the pitch-line, the sliding action is rapidly increased. In trying to adapt the bevel-gear drive to heavier trucks that require greater gear-reductions we must sacrifice efficiency by using

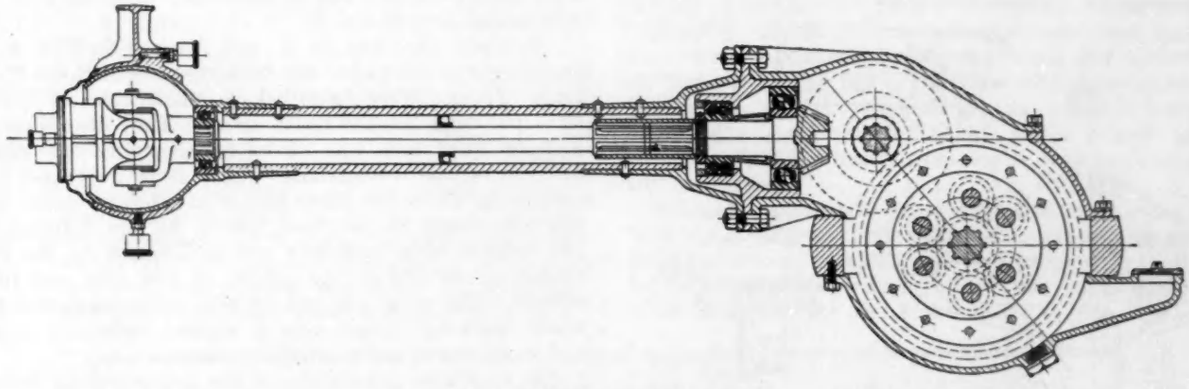

Fig. 4—Double-Reduction Axle

This Type of Axle Unquestionably Has Shown the Greatest Increase in Popularity Under Heavy-Duty Vehicles. In the Spur-and-Bevel Type, the Gears Can Be Enclosed in a Single Casting, and It Is Possible To Select Spur and Bevel Pinions with a Sufficiently Large Number of Teeth for High Efficiency, Together with a Heavy Pitch, and Satisfactory Cross-Sections for the Ring-Gears To Hold the Distortion Following Heat-Treatment Within Reasonable Limits. Its Efficiency Is High Throughout the Working-Range, and Changes in Ratios Can Be Made Quickly Without Serious Effect on the Various Components

under light trucks, and from present statistics it appears that no American builder permits its use with solid tires. Pneumatic tires are a guarantee against overload and reduce shock stresses very materially. The spiral-bevel gearset is most commonly used in this Country and is almost as efficient as the straight-tooth type. The spiral bevel has a heavy additional thrust, which slightly decreases its efficiency, but with poor adjustment the spiral bevel shows a slighter loss and is much more durable than the straight-tooth bevel-gear.

In the Gleason Works' bulletins it is stated that 10 teeth in the bevel pinion is a minimum practical number for satisfactory operation, but it advises the use of not less than 12. A reduction in the number of teeth brings about a loss in efficiency because the rolling action between a small number of teeth in the pinion or a very large number of teeth in the ring-gear. A large ring-gear reduces road-clearance and body-clearance and presents a serious problem in heat-treating. The distortion of the relatively small section and of the individual teeth in the gear results in high-spots and unevenness, causing noises, and sets up unusual stresses. Regardless of these serious objections, some companies try to adapt the bevel gear to larger trucks, although the first company to try it out gave up the attempt and decided to use the double-reduction type of rear axle.

A European truck introduced recently into this Country has a 5-ton axle with straight-tooth bevel-gears; it is used with solid tires. A 7-tooth pinion and a 56-tooth ring-gear are used. This gives only an 8 to 1 reduction;

whereas, most 5-ton trucks in this Country require at least a 10 to 1 reduction. An inspection of the European truck shows that the ring-gear is very large, the pinion has a surprisingly small number of teeth, and the bearings run into special sizes, particularly the pinion bearing, which is much larger than the pinion in diameter. In this axle the pinion is the "neck of the bottle;" the power that can be transmitted through it, and its wearing life are the limits to satisfactory operation. It is more than likely that a double-reduction axle could be built at the same cost, with a 13-tooth bevel-pinion, which would give greater total efficiency in spite of a loss in each set of gears, and would certainly increase the wearing life by cutting the tooth-pressures in half.

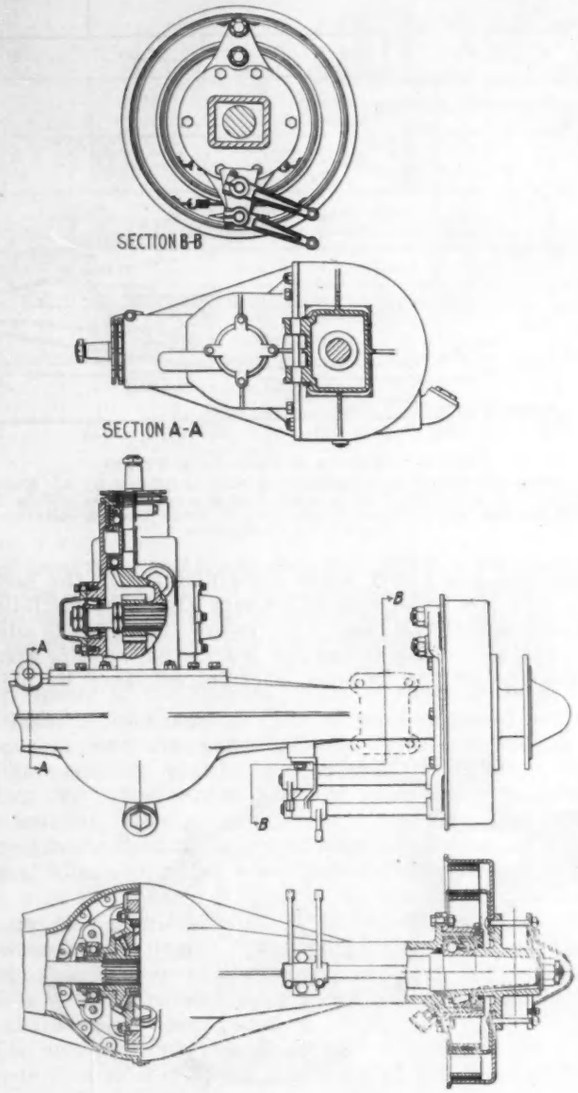

FIG. 5—A NEW DESIGN OF BUS-AXLE
Bus and Coach Design and Development Has Brought Out the Need for Better Brakes, Better Springs, a Lower Center of Gravity for the Loaded Vehicle and Smoother Operation. All These Will Be Reflected in Future Design

It will be observed that for 6 years the worm-drive truck-axle has been more popular than all other types combined, whether we figure on number of models offered or total production. For any given reduction, it is possible to obtain a suitable gear-center, a favorable lead-angle and a low tooth-pressure, which will result in extremely high efficiency at a normal operating speed. Unfortunately, if an axle is laid out with these factors favorable, changes in ratio affect the efficiency; we must change ratios accordingly if the axle is to be used in flat districts, in hilly districts or at great altitudes where the loss of engine power must be compensated for by increased gear-reduction. Any change in the ratio affects the loads on the worm and the differential bearings to such an extent that one set or the other must be oversize to take care of the wide range of ratios; in some the end-thrust is great and in others the side-thrust is great. If the centers are not laid out large enough, the tooth-pressures become heavy with danger to the maintenance of an oil-film. On account of the sliding contact of the gears, the friction loss is considerable at low speeds, although it approaches that of rolling friction at high speeds.

The worm drive has demonstrated its commercial efficiency by maintaining its lead through many years; while its mechanical efficiency is not the highest, it has justified its existence. On account of its high rating, it has been subjected to attack by advocates of other forms of drive. Some of these attacks are distinctly misleading. For example, torque tests are shown which claim continuous losses of as high as 40 per cent, and the inference is made plain that this loss is between the worm and the gear. While such losses may occur in the complete axle-assembly, they cannot possibly be attributed to the worm and the gear alone, as that amount of work converted into heat would result in rapid failure of the worm and the gear. The tests, therefore, indicate not the efficiency of the worm and the gear but the losses due to bearings, workmanship, poor lubrication and so on.

The tests reported by S. von Ammon in Fig. 36 and in the text of his paper An Investigation of Some Heavy-Duty Truck Drive-Axles[2] show efficiencies as high as 92½ per cent for the worm drive. They also show that a 3 per cent loss was offset by changing the type of bearing on the worm shaft. These tests were also interesting in showing that the internal-gear axle is inefficient under torque load, owing to the distortion of the transmission members and differences in the lubricating conditions at the center of the axle and in the wheels. The most efficient type of axle, considering the whole working range, was a geared reduction axle in which all gears were centrally located.

The declining popularity of the internal-gear drive as shown in Fig. 3, may be due to the fact that its price at present is not as low, compared to other types, as it was several years ago. The chain drive has gradually dropped to a very small percentage, but it probably will remain in the field as some users prefer it to any other type. Both of these designs, however, probably will continue to show a gradual lessening of popularity as the other types of enclosed drives are improved in construction and lowered in cost. The internal-gear type, in which the wheel gears are enclosed in an oil-chamber, has the disadvantage of very high cost, with a loss of efficiency under heavy load, due to the misalignment of the central gear-case and the wheel gear-cases. The oil nuisance attached to removing wheels for tire changes and brake inspections is a serious objection.

UNSPRUNG WEIGHT

All axle manufacturers are trying to reduce unsprung weight. It has been established definitely, however, that low unsprung-weight is not the greatest requirement;

[2] See THE JOURNAL, June, 1923, p. 517.

otherwise the chain drive would lead in popularity. The von Ammon tests demonstrated plainly that the strength and the cross-sections of the load-carrying members must be sufficient to hold the misalignment under torque loads to the minimum. Considering the heavy spring-pad loads, no axle can be efficient unless the load-carrying member is stiff enough to prevent serious deflection. Better materials will not offset deflection, if suitable sections are not provided.

The double-reduction axle unquestionably has shown the greatest increase in popularity under heavy-duty vehicles. In the spur-and-bevel type, the gears can be enclosed in a single casting and it is possible to select spur and bevel pinions with a sufficiently large number of teeth for high efficiency, together with a heavy pitch, and satisfactory cross-sections for the ring-gears to hold the distortion following heat-treatment within reasonable limits. Its efficiency is high throughout the working range and changes in ratios can be made quickly without serious effect on the various components. It is interesting to note that this type of axle was chosen by leading British experts for the heavy-duty British subsidy war-trucks. It is illustrated in Fig. 4.

We are asked why leading axle manufacturers do not publish comparative efficiency tests on their products. If an applicant for a position were to present a recommendation signed by himself, he would be laughed out of your presence even though what he said were true; if his personal recommendation condemned all other applicants, he probably would be thrown out. It is amusing to note from some of the tests that have been displayed that power transmissions through a series of gearsets and bearings, none of which exceeds 98 per cent in efficiency, are shown to have a total efficiency of 98 per cent, although 0.98 x 0.98 x 0.98 only equals 0.94 and a fraction.

The most desirable features of each type of axle shown in Fig. 3 might be listed as folows:

(1) *Worm.*—Quietness and simple construction
(2) *Bevel-Gear.*—Low cost
(3) *Chain.*—Light unsprung weight
(4) *Internal-Gear.*—A saving in size and weight of transmission members due to the final reduction
(5) *Double-Reduction.*—A satisfactory combination of highly efficient gearsets enclosed in a single gearcase, not affected materially by pay-load deflection or ordinary changes in gear-ratio

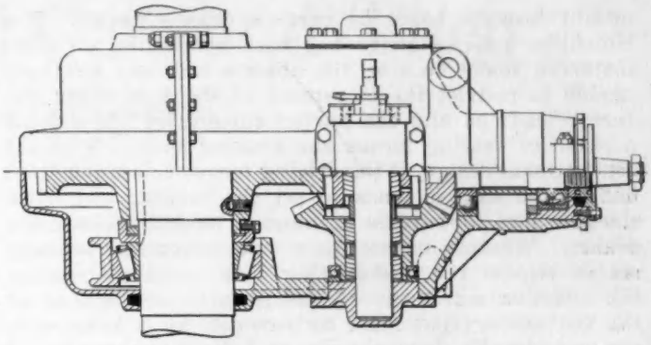

FIG. 6—FOUR-WHEEL-DRIVE RAILROAD-AXLE
The Introduction of Gasoline Power for Railroad Cars May Also Have an Effect on Automotive Products. This Is an Illustration of a Railroad Axle Arranged for Four-Wheel Drive and Providing Gear Positions for Idling and for Reverse Driving, with the Use of All Transmission Speeds in Either Direction of Travel

FUTURE CAR AND TRUCK AXLES

Every truck axle represents a compromise in which some desirable features are sacrificed to obtain the features considered most valuable by the designer. In future axle design, we have the following things to influence us: Balloon tires, with a consequent reduction in the brake-drum diameters; greater reductions and more steps in the transmission; a desire for greater road-clearance and body-clearance; a desire for more satisfactory brakes; and, possibly, the use of three or more axles, two or more being driving axles, to obtain greater safety, better load-distribution and better traction, with less damage to roadbeds.

Balloon tires may force the use of wider-tread axles in the passenger-car field. The 20-in. wheel makes it impossible to use a brake-drum much over 16 in. in diameter. As a result, we may look for disc brakes on the wheels of heavy vehicles and may expect disc brakes on the propeller-shaft; as some builders are adopting propeller-shaft brakes, while others are discarding them, the brake situation is sure to provide food for thought.

Axle manufacturers surely approve of the use of hydraulically and of pneumatically operated brakes as a solution of one of their greatest problems; that is, obtaining sufficient movement of the axle brake-levers after allowing for the lost motion of the brake levers

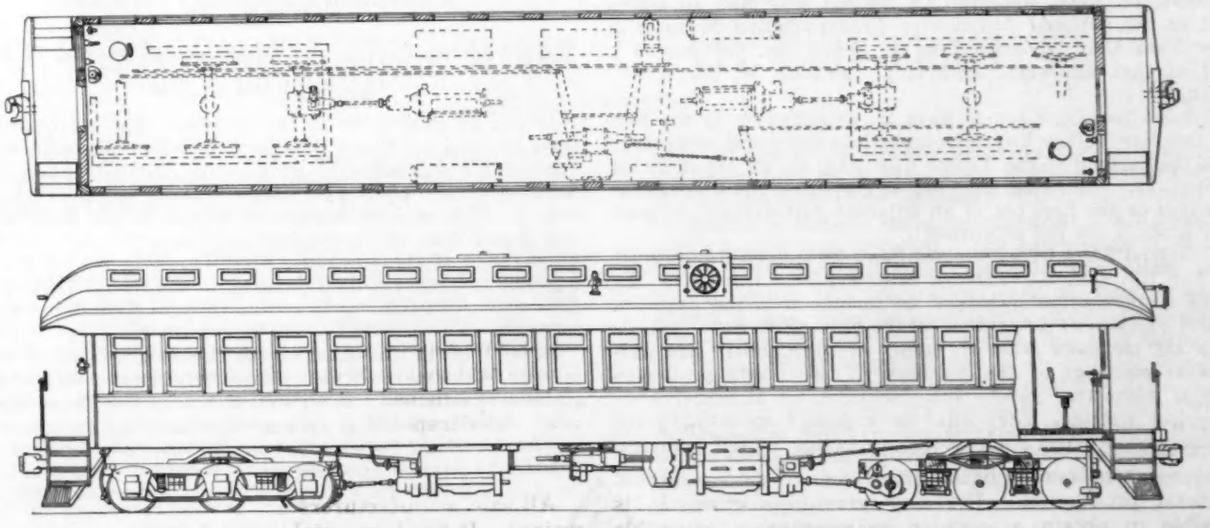

FIG. 7—INSTALLATION OF FOUR-WHEEL-DRIVE RAILROAD-AXLE
This Installation Is Typical for the Axle Shown in Fig. 6

usually brought about by careless chassis design. The Hotchkiss type of drive has been condemned in some instances solely because the chassis engineer has been unable to restrict the movement of the axle under different loadings and the partial turning of the axle as a result of driving torque and braking loads. With the conventional design, if the driving torque raises the front end of the axle it tends to set the brakes; and when the axle tilts forward in braking, it tends to release the brakes. Whether or not these axle movements actually set or release the brakes, they most certainly restrict the effective movement of the brake lever because of the lost motion that must be provided for. Axles with air or hydraulic chambers mounted directly thereon and with flexible connections to the chassis obviously will require no lost motion in the brake levers to make up for axle movements with relation to the fixed points on the chassis.

It is easily demonstrable that, if the rear wheels of the conventional type of truck are dropped in a chuck-hole, it is difficult to pull the truck out of the hole without speeding-up the engine and dropping in the clutch suddenly so that the rear wheels will ride over the obstruction before they start to slip. From the laws of sliding friction, we know that once the rear wheels start to slip, the adhesion between the tire and the road is lost; and the more rapidly the tire slips, the lower the coefficient of friction becomes. The slower the rear wheels revolve, the greater the coefficient of friction is and the greater is the possibility of climbing out. Such conditions as these demonstrated the usefulness of lower transmission-ratios and resulted in the use of two transmissions in tandem. A careful driver will pull out of a hole without injury to the axle but, if care is not used, such transmissions inevitably bring about the destruction of the rear axle.

Every 3½-ton axle in common use was designed for a maximum total reduction of approximately 70 to 1 with the conventional-size engine for a 3½-ton truck. If this size of engine is used in a 3½-ton truck fully loaded, and total reductions of 175 to 1 are brought into action, the result must be the destruction of the axle if the full torque of the engine is transmitted. If these extra-speed and range transmissions bring about the use of smaller and more economical engines, their introduction will be a step forward. To date, transmissions have been designed to operate approximately 5 per cent of the time the truck is in service, and any attempt to operate them from 50 to 100 per cent of the time can result only in trouble, unless the additional use is provided for by changes in design. The interest in these transmissions leads us to believe that the two-speed rear-axle will be in demand very soon; at least one company is now using a form of two-speed rear-axle.

The bus and coach design and development has brought out the need for better brakes, better springs, a lower center of gravity for the loaded vehicle and smoother operation. All these will be reflected in future design. Fig. 5 shows a new design of bus axle.

The introduction of gasoline power in railroad cars may also have an effect on automotive products. Fig. 6 shows a railroad axle arranged for four-wheel drive and providing gear positions for idling and for reverse driving, with the use of all transmission speeds in either direction of travel. Fig. 7 shows a typical installation of this type of axle.

MEETINGS OF THE SOCIETY

(*Concluded from p.* 181)

day's trials, marks of merit and demerit will be given the cars and the winner determined by comparing the scores of the respective competitors. Certainly the idea is novel and should give the Buffalo members a good picture of how such tests are conducted. A dinner will be served in the evening.

New England Section will open its season on the evening of Sept. 17. The Metropolitan Section will take an active part in the national Automotive Transportation Meeting in New York City by scheduling its September meeting as a part of that important gathering. Francis W. Davis will speak.

Chicago members are to have an opportunity to see how the familiar Yellow Cab is brought into the world when they visit the factory of the Yellow Cab Mfg. Co. on the morning of Sept. 19. Following luncheon at the plant, the Chicagoans will taxi to the first tee of an adjacent golf-course and compare stances for the afternoon.

Cleveland Section has selected Sept. 22 to open its program for the fall season. Thomas Midgley, Jr., will give the Washington Section members an insight into the chemical control of gaseous detonation on the evening of Sept. 26.

Society members from all points in the Country are welcome at meetings of the Sections. These meetings always provide interesting papers and discussions on automotive engineering matters. They offer an excellent opportunity for members to broaden their acquaintanceship in the industry. If you reside in the territory of any one of the 12 Sections, by all means become a member of the Section and enjoy the programs that are to be provided for you during the coming fall and winter season.

WORLD FLIERS TO SPEAK

Will Address Aeronautic Meeting in Dayton If Flight Is Completed in Time

It will be good news to the members that permission has been granted by Army Air Service authorities allowing the round-the-world pilots to address the national Aeronautical Meeting of the Society in Dayton, Ohio, on the evening of Oct. 2. This will be during the period of the International Air Races that are to be held in that city. Of course the appearance of these intrepid fliers is contingent on their being able to complete their journey to the Pacific coast during September, but this seems not unlikely as THE JOURNAL goes to press.

In addition to this feature, the members will be privileged to hear a summary of the progress in naval aircraft design given by Commander H. C. Richardson of the Navy Air Service. Details of the program will reach the members in a special *Meetings Bulletin* as soon as they are definite.

Automotive Rail-Cars and Their Development

THE three papers treating this subject were presented at the Mid-West Section Meeting held April 11, 1924, at Chicago, and each paper was printed in full in the June, 1924, issue of THE JOURNAL. Both the automotive and the railroad standpoints are presented and agree in indicating that the future success of the motor rail-car is assured. The comments and criticisms advanced by the automotive and the railroad engineers present, as well as those submitted subsequently in writing, are significant and optimistic. This discussion is printed in full herewith, preceded by abstracts of the papers.

THE MODERN MOTOR RAIL-CAR

BY M. L. McGREW[1]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

BECAUSE of tremendous demand for mass-transportation over long distances in this Country, railroad equipment has become less and less suited for small transportation needs; but a large amount of small-unit transportation exists which can earn a profit for the railroads if they have the equipment best suited to handle it. Gasoline-propelled rail-cars have demonstrated their ability to meet the needs of this small-unit traffic. Types of such rail-cars now operating range from 30-passenger or 10 tons of freight capacity to 60-passenger or 30 tons of freight capacity; in certain services, their capacity can be increased by using trailers and by running them in trains operated by one driver at the front end, who has them under multiple-unit control, at speeds up to 50 m.p.h. and for from 20 to 50 cents per car mile. Recently developed rail-cars are about 55 ft. long, have a useful car-floor area 9 ft. wide, weigh about 60,000 lb. when loaded and require about 1 hp. for each 500 lb. of weight.

Rail-cars propelled by electricity from storage-batteries, by electricity from a gasoline-engine-driven generator through electric motors on the axles and by similar means from power generated by a Diesel engine are mentioned, as well as hydraulic transmissions used instead of electric drive, and cars equipped with large single engines and mechanical transmissions, with comments on their varied performance. Development of multiple-unit control for rail-cars has not presented great difficulties, the main one being sufficient dependability on the power unit for its operation without attendance. This system of control and the mode of synchronous operation of several power units are treated briefly and the rail-car field is surveyed.

Specific rail-car development as reported in the paper includes the reasons governing the determination to use an individual power unit of 60 hp., clutch requirements and design and other elements that can be compounded in various ways to produce rail-cars capable of meeting almost any one requirement. The rail-car design adopted by the company the author represents is analyzed, this being a four-wheel power-truck having an engine and transmission and driving to one axle, as well as gasoline supply, cooling and exhaust systems, an air compressor and an electric generator; a car body suited to the needs of the purchaser; and control equipment, these three elements making possible many combinations to meet specific services, some of which are mentioned. The detail design of the various units is then discussed in sequence.

MOTORIZED RAILROAD EQUIPMENT

BY E. J. BRENNAN[2]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

A BRIEF summary of the history of motor rail-car equipment on the railroad represented by the author is given in his paper. Three gasoline-driven rail-cars were put into operation in 1910. The engine used for each car was a six-cylinder, 10 x 12-in., slow-speed, four-cycle reversible-type having overhead valves, an open crankcase and a 200-hp. rating, but experience has proved that the four-cycle reversible-type engine equipped with an air-operated starting-apparatus makes rather a complicated unit that is the cause of many difficulties. Details are given concerning these first three cars, their performance and the changes made in their equipment.

In 1922, a two-car train consisting of a motorcoach and a trailer was installed. The coach is 28 ft. long, has a 12-ft. baggage-space, carries 30 passengers and weighs 28,000 lb.; the trailer is 32 ft. long, weighs 17,000 lb. and seats 36 passengers. Equipped at first with a four-cylinder 65-hp. engine, this was found to be of insufficient capacity and a six-cylinder 105-hp. engine was substituted. Other changes have been made since and these are specified. Experience with the rail-cars thus far specified showed that any future units, and particularly two-car trains, must be of light construction and of sufficient ruggedness to operate on steam-railroad lines.

The next installation was a single-unit rail-car weighing 30,000 lb. and having capacity for 38 passen-

[1] International Motor Co., New York City.
[2] Superintendent of motive power, Chicago Great Western Railroad Co., Oelwein, Iowa.

gers. It has a 65-hp. four-cylinder engine and operates very successfully over a daily 185-mile run through level territory. After inaugurating a new set of motor rail-car stations at public-highway crossings along this route, passenger business for this particular unit increased.

A train consisting of a large motorcoach and a trailer, powered with a 225-hp. marine-type engine, was then installed and operated over a 216-mile route. The coach seats 30 passengers and has a 16-ft. baggage-space; the trailer seats 44 passengers. These gasoline-propelled rail-cars and trains are driven by steam-railroad engineers. The last-mentioned train has operated so successfully that the company has ordered two more similar trains of even larger capacity and, in addition, a gasoline-electric single-unit rail-car. The operating and maintenance cost figures for the different types of equipment mentioned are presented in tabulated form.

Some general requisites for stability, reliability and low total costs for rail-car utilization are that an engine of sufficient capacity be provided to enable it to operate normally at not more than 60 or 65 per cent of its maximum power; that lighting arrangement, current generation and current storage be improved; that passengers be made more comfortable; that the cooling capacity be made ample for the engine; that U. S. Standard and not S. A. E. Standard bolts and nuts be used; that all parts be made accessible and that parts be standardized.

MOTORIZATION OF "LIGHT-SERVICE" RAIL-TRANSPORTATION

BY E. WANAMAKER[3]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

ASSIGNING the cause of failure to develop railroad light main-line and branch-line transportation satisfactorily as having been the necessity of concentration by railroad officials on the problem of moving heavy transportation-units over long distances, and stating that a general acknowledgment has been made by all concerned that the steam locomotive for railroad light-service traffic has proved to be unsatisfactory, the author discusses the types of internal-combustion-engine power-units best suited for rail-car propulsion.

Three prime requisites to the development of such equipment are economical production, economical operation and a high quality of service rendered. No particular benefit will be derived from introducing internal-combustion-engine drive to railroad service by making minor improvements to such equipment as has been built for other services; rather, it is necessary that engineers work along the lines of radical changes and radically new developments.

For economic reasons, two types of internal-combustion-engine-driven rail-cars should be standardized, one of about 60-hp. and the other of about 300-hp. power-unit capacity. The former would use gasoline as fuel; the latter, the type of fuel suited to Diesel engines.

The use of such standardized commercial engines, of limited horsepower but installed in multiple in a given rail-car, would provide a satisfactory system. Engines, clutches and transmissions of approximately the 60-hp. size have been developed to a satisfactory degree for the heaviest and hardest truck-service and, with the intelligent mounting of these engines and units on a rail-car or on a light locomotive truck, together with a suitable multiple-unit-control system, the successful solution of the rail-car problem for all except the heaviest class of light-service traffic is offered.

Differing radically from the 60-hp. powerplant, the 300-hp. unit would be driven by the latest type four-cycle multi-cylinder Diesel engine at an engine speed not to exceed 650 r.p.m. It would use a system of fuel injection and distribution that would eliminate high-pressure-air-piping, the spray air-bottle and similar parts; would operate at constant speed and depend upon electrical transmission to satisfy the variable torque and speed requirements of the locomotive. Primarily, it would be used as a locomotive, flexibility as regards capacity being secured by using any desired number of generators and motors in multiple, in one or more rail-car units.

[3] Electrical engineer, Chicago, Rock Island & Pacific Railway Co., Chicago.

[4] Vice-President and general manager, Climax Engineering Co., Clinton, Iowa.

THE DISCUSSION

JAMES T. ST. CLAIR:—We all recognize that in every railroad system a large field for motor rail-cars exists. One requisite is that they have reliable motive power. The work undertaken by the Chicago Great Western and other railroads, as outlined, will go a long way toward overcoming the difficulties that have been experienced and be of great assistance to the manufacturers of this class of equipment in perfecting their designs to provide for greater reliability of operation of such cars.

C. T. RIPLEY:—I wish to emphasize the importance of what Mr. Wanamaker has said. When we analyze the problems on our railroad, one of the first things we note is the necessity of increased capacity on the type of branch-line service we have. I realize that some Eastern railroads are in a different position. The mixed-train service enters into this branch-line problem and I think Mr. Wanamaker's suggestion regarding the possibility of using the Diesel type of locomotive may be the answer for this type of service. Ordinarily, the light motor rail-car does not take care of the conditions that we have on our Western lines, which are not essentially branch-line railroads.

GEORGE W. CRAVENS[4]:—The company with which I am connected builds internal-combustion engines. We have now in our shop a 300-hp. Diesel engine that will weigh about 40 lb. per hp. Its nominal operating speed is 600 r.p.m., but we may be able to get an average speed of around 720 or 750 r.p.m., and successful control down to 450 r.p.m. In other words, it is possible to build a Diesel engine for variable speeds and to build an engine of *less* than 60 lb. per hp. The engine has six cylinders and is only 10 ft. 6 in. overall. This first engine of ours is being developed at the request of one of the large companies for use on motor rail-cars and gasoline-electric locomotives. It is a two-cycle engine. We can supply from one to eight cylinders, and can assemble odd numbers as well as even numbers of cylinders because it is a two-cycle engine.

From 1897 to 1899, I had charge of locomotive design for the General Electric Co. We built a number of locomotives in those 2 years. Our struggle was to

simplify rather than to complicate the control system. I believe that the more parts you leave out the better, provided the apparatus will work. I am a radical when it comes to simplification. I have had a number of years of experience with all kinds of apparatus and believe that it is not sensible to expect the average railroad man to handle his equipment in the same manner as the trolley-car and the motor-truck men handle their equipment. When you put the two together, I think you are piling it on too thick. Again, and as a result of my railroad experience I believe it is not possible to build a gasoline engine to mount directly on the truck and have it stand the pounding of the railroad service.

Mr. Brennan is right when he says we must make the railroad equipment heavy and use U. S. Standard thread pitches in it. We use the S.A.E. Standard threads on our engine, but I believe that if we are to sell equipment that will be easy for the railroads to maintain, we must use U. S. Standard threads. One of the first things we learned in the electric-locomotive business was to use larger bolts than the calculations called for, because the men who make the repairs take a wrench about 2 ft. long and lay on it to set the bolts up.

L. C. JOSEPHS, JR.[5]:—I, too, was with the General Electric Co. for many years in its locomotive department. Since 1898, its electric-motor design has progressed much farther than it had when Mr. Cravens was there. We now build controls that are very much simpler than anything he may have seen in those days. The control circuits on one of these rail-cars are very simple, more so than those of the lighting and starting equipment on some automobiles.

Mr. Brennan's paper is very interesting to me because of the very large experience he has had with many different kinds of car. However, I take exception to two points he made because, if these are well founded, I question whether the automotive industry as a whole would have any further interest in the development of motor rail-cars; in other words, I believe the rail-car development would be left to locomotive works and the like.

Regarding Mr. Brennan's objection to the use of S.A.E. Standard threads anywhere in the design of rail-cars, when I was engaged in field work on gasoline-electric cars for the General Electric Co. in 1911, one of the first recommendations I made to our engineering department was the elimination of all A.L.A.M. threads, as they were called then. After having much more experience with these cars on both the operating and the manufacturing side, I feel that this was a mistaken recommendation and that we absolutely must stick to S.A.E. Standard threads in the places where S.A.E. Standard threads are required and that, if railroad companies insist on a change regarding this matter, we might as well discontinue the production of motor rail-cars.

There are several reasons why we should use S.A.E. Standard threads. Because of the locations in which they are used, they are standard in regular production and a change would mean additional cost, which alone would outweigh the cost of the extra stock of S.A.E. Standard parts that a railroad would have to carry; but the more important reason is that, with hardly an exception so far as our own designs are concerned, the parts that are made with S.A.E. Standard threads are made of special alloy-steels heat-treated and individually inspected, and we do not want any possibility of having a customer substituting an ordinary store bolt for these parts. If it shall be necessary to change the design so as to omit such high quality materials and so that the average village blacksmith can make the necessary spare parts, we shall be throwing overboard all the advances of the automotive industry, including the very factors that have made the rail-car possible; and we might just as well stop any further development now. I am heartily in accord with the use of U. S. Standard threads wherever possible. In our own designs we are using them for all the ordinary truck-construction parts which we expect the railroad company to service. But we do not want to have the railroad company substitute inferior material in such places as connecting-rod bolts. Of course, the main reasons for the use of S.A.E. Standard threads are their greater strength as compared with that of the same sizes of U.S. Standard, and their closer adjustability and capacity to remain tight. Railroads that have the facilities to heat-treat and make parts certainly should not object to purchasing a small supply of taps and dies. Railroads that have not these facilities should secure their spare parts from the manufacturer and run no risk of using inferior material.

As to Mr. Brennan's second point, that no automotive units developed for commercial service will ever be successful in the motor rail-car field, I feel that this indictment of our entire industry is not based on a sound premise; for I do not believe that Mr. Brennan's railroad has tried out either a majority or by any means the best of the many types of automotive equipment on the market. Having been engaged in the design of locomotives for a number of years before coming into the automotive industry, it has been my experience that the service of the heavy-duty motor-truck is considerably more severe than locomotive service. Factors of safety have to be made almost double and the quality of design and of shop workmanship have to be of a much higher order. There are some differences, however, in highway and railroad service and I believe it probably is on this basis that Mr. Brennan made his statement. In the first place, as he pointed out in his paper, the amount of horsepower provided on a motor rail-car should be such that the average performance will not utilize more than 60 per cent of the available power. Very few automotive engines on the market will carry 100 per cent load continuously without distress. Even if some of these engines are chosen for motor rail-car work, it would not be good practice to design the car so as to use the maximum output, as some excess power should be provided for making up time and the like.

Another difference in automotive and railroad practice is the mileage between overhauls. The ordinary automobile makes from 5000 to 10,000 miles per season, and slow-speed motor-trucks make possibly at most 10,000 miles per season. Many railroad men feel that the motor rail-car service is much more severe because the cars make perhaps 35,000 to 40,000 miles per year; that, therefore, the equipment requires special design. This mileage, however, is not a serious matter. Taxicabs sometimes run more than 100,000 miles per season. The company with which I am connected has had some buses in service which have run more than 200,000 miles in 20 months. Automotive equipment will make mileage just as well if not better than railroad equipment, provided it receives ordinary inspection and care.

I agree with Mr. Brennan's statement that it is not possible to take a miscellaneous collection of automotive parts and put them together to make a motor rail-car, but I cannot agree that properly built units designed along automotive lines to work together cannot be used, even though these units may be used in other fields of

[5] Engineer, International Motor Co., Allentown, Pa.

the automotive industry. If this cannot be done, we might as well discontinue our efforts in the motor rail-car field, as the volume of business in it is much too small to carry the overhead of a special industry.

E. J. BRENNAN:—If Mr. Josephs will refer to my comments he will note the following: "All bolts and nuts, wherever possible, throughout the entire equipment, should be U. S. Standard instead of S.A.E. Standard." This does not imply necessarily that a connecting-rod bolt or a spark-plug, which I will agree should have S.A.E. Standard threads, should be converted to U. S. Standard, although many high-speed steam-engines have U. S. Standard nuts and bolts on their connecting-rods. Many other appurtenances are fastened with bolts and nuts that should be made U. S. Standard because the preponderance of U. S. Standard appurtenances over S.A.E. equipment on steam railroads is so very much greater.

With reference to the second point mentioned by Mr. Josephs, we have tried what has been recommended to us as the best automotive practice and it has not given us the service that we demand of steam-railroad parts. Automotive units now used in steam-railroad service carry about 500 lb. per hp. as compared to about a 200-lb. maximum on buses. The shocks and strains that units of equipment in steam-railroad service are subjected to are far more severe and pronounced than those in commercial highway service. This information is based on actual experience.

L. G. PLANT[6]:—Being associated with neither the users nor the builders of motor rail-car equipment, I find it difficult to suggest any phase of the subject that has not been covered in Mr. McGrew's admirable paper. As an observer from the side-lines, however, I have found certain problems in the design and adaptation of self-propelled rail-cars very interesting. These have led me to formulate certain very definite opinions in regard to the adaptation of such equipment to steam-railroad service.

First, with reference to the specifications of the equipment, the railroads and their regulating bodies must be willing to accept considerable modifications in respect to the weight and the structural strength of these cars in comparison with the all-steel passenger-car standards of today. Bear in mind that a very satisfactory gasoline-propelled motor rail-car seating more than 40 passengers has been built that weighs less than does a single six-wheel truck now used under a standard Pullman sleeping-car.

In regard to capacity, a field exists for any size down to 30 passengers. Some of the best patronized and most profitable examples of gasoline motor rail-cars in railroad service have had a very limited capacity but, generally, steam-railroad officials have not found it practicable to adapt their operating conditions to suit the smaller units; so, apparently, the builders have been forced to the construction of larger cars or to a plan for the multiple operation of a number of units, as described in the paper.

But, whether the capacity requirements are met in a single high-powered rail-car or in multiple power-units, it is essential that each gasoline motor rail-car train be equipped with more than one engine. With all their other faults, it is probable that gasoline motor rail-cars of older design would have been reasonably successful had it not been for the engine failures that so frequently tied-up the equipment on the road or in the terminal. The steam locomotive will never be displaced generally by gasoline-engine-propelled equipment that is dependent upon the operation of a single engine for its regular performance.

In this connection it is interesting to know that one Eastern railroad is seriously contemplating the substitution of gasoline-electric locomotives for steam motive-power in both main and branch-line service. This would involve neither the use of the Diesel principle nor a departure from conventional gasoline-engine and electric-motor equipment, but a multiplication of standard gasoline-engine units driving electric generators and the customary electric-motor drive. While such an arrangement might be improved upon, it is well within the range of a practicable capacity, weight and first cost for general railroad service.

The development of a gasoline motor rail-car adapted generally to railroad requirements is yet a pioneer undertaking. Having observed the progress made in recent years toward the latest design of motor rail-cars, I am impressed with the courage and patience that have been required to accomplish this result. With the cooperation of the railroads, it is certain that so sincere and well directed an effort will lead to lower operating costs and better service through general usage of motor rail-cars.

[6] Assistant to president, National Boiler Washing Co. of Illinois, Chicago. Formerly technical editor of *The Railway Review*.

RUSSIAN AGRICULTURAL EXPORTS

A FACTOR not to be ignored in any consideration of the outlook for Russian agricultural exports is the development that has taken place in other grain-growing areas of the world, especially Canada, Australia and Argentina. In the 5 years, 1908 to 1912, the combined average production of wheat in these three countries was 413,000,000 bu. and their combined net exports were 223,000,000 bu. Their combined crop for 1923-1924 was almost 850,000,000 bu. and their exports during the wheat year 1923-1924 are estimated at about 550,000,000 bu. The world does not need Russian grain as it needed it in 1913.

As an exporter of grain to the neighboring countries of Europe, Russia has the advantage of contiguity to its markets. From this standpoint its competitors are Bulgaria, Rumania and the plains of Hungary. Its second great advantage is the fact that its peasantry have a very low standard of living, which is the equivalent of low wages. Wages are measured in terms of efficiency, however, and it is not certain that Russian peasants are cheap grain-growers when this test is applied.

Against these are the advantages of Canada and other new grain-lands where natural fertility, large-scale methods of production and bulk handling, together with modern and adequate transportation facilities, are important offsets to the advantages accruing to Russia. Seed selection, clean handling and careful grading are also important influences in favor of Canada and perhaps to a less extent the other newer countries. It is a safe conclusion that unless Russian methods of grain growing and handling are altered radically, Russian grain cannot compete on a quality basis with wheat grown in North America, Argentina and Australia. It is difficult to find in the agricultural situation any basis for great expectations of foreign trade.—E. M. Miller, National Bank of Commerce.

Vol. XV September, 1924 No. 3

Industrial and Commercial Applications of the Tractor

By G. D. Babcock[1]

Chicago Tractor Meeting Paper *Illustrated with* Photographs

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

At the close of the war the material and equipment available for the construction of tractors for commercial purposes consisted mainly of the war tractors that were then being produced. It was essential that the tractors should find their own uses. Many parts and many of the mechanical operations of what had been the ordnance tractor have since been changed in adapting it to commercial purposes but the general appearance has remained the same. Heat-treating the cast steel used for track shoes has increased both its life and its strength. The various operations of tractors, including those in timber lands, both in snow and in swamps, are shown by photographs, the industrial rather than the agricultural phases being especially enlarged upon.

Caterpillar trailers make hauling easy but are more expensive than wagons; with tractors they are replacing dog-sleds in Alaska. Winches are used to work over ground that otherwise would be inaccessible.

The life of the track is said to be about 3000 miles but 5000 miles has sometimes been obtained and is the point aimed at. Observations of loose space-blocks in shoes indicated that they gave more satisfactory service than tight ones, so the loose or rolling type was adopted. As a lubricant for the track, grease is used when operating in mud; oil, when operating in dry soil. Changing the position of the holes in the shoes was found to relieve the packing of snow between the sprocket and the track-shoe. The size of the calks also is important and depends on the hardness of the surface of the road. The side-draft of the tractor becomes a grouser problem when the tractor is used in street-cleaning, as in New York City, because the grouser must hold, yet not damage, the pavement.

The use, with tractors, of various accessories, such as rotary snow-plows, timber-cutting machines, road graders and scrapers, and operations such as the scarifying of old asphalt, Southern logging and the swabbing of oil-wells, are described.

In looking over the subject on which I am to speak, I am very happy that the representatives of the Society have been so kind to me, not being a tractor engineer, as to select a subject that avoids engineering discussion. I should like to introduce my talk with that statement. The paper will be limited strictly to the industrial and commercial applications of the tractor. The illustrations are fairly typical of the applications of tractors to various industrial and commercial operations. If they happen to be somewhat spectacular, I think that they will be equally convincing and useful.

We have very little activity at our Peoria plant in the matter of agricultural tractors; our efforts are devoted largely to industrial machinery. We have had many problems to meet from an engineering standpoint. It may be well to recall that after the close of the war our plant took over the material and equipment left from the war tractors that were then being produced, and from them we found it necessary to build a commercial organization, and with that commercial organization to develop and spread a commercial product. The problem of complete reorganization after the war found nothing but war material from which to make commercial applications; it was essential that the tractors should find their own uses; and if we have been acute in recognizing that fact and in establishing our processes so that they should lead to the developing of a machine to meet the requirements that can be satisfied by the tractor, that may have been the one interesting phase of our development.

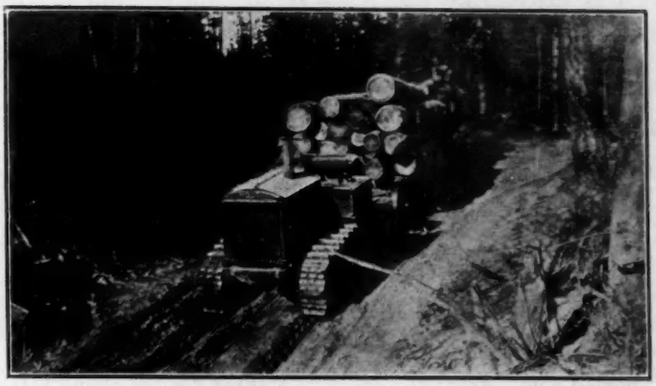

Fig. 1—Dry Mountain Logging in the Northwest
The Pitch of the Slope Is Steep and the Timber Is Tall and of Relatively Large Cross-Section

From time to time I shall endeavor to indicate some of the problems that we have had in correcting the design, and what the result of those corrections has been. In one operation, the correction of the flow of the Missouri River, it was necessary for the tractors to work in sand while submerged in water and sand off the shore. A great many parts and many of the mechanical operations of what was the ordnance tractor have been changed in adapting it to commercial purposes, but the general appearance of the tractor is roughly the same.

The Heat-Treating of Track-Shoes

The heat-treating of the cast steel for the track-shoes was a development by Mr. Grotts at Peoria and, working in conjunction with the steel foundries, we succeeded in getting cast steels that alone were not of marked value but could be heat-treated and otherwise prepared so that they had long life and great strength. As I remember, in the early days and even in some of the late years of automobile work, cast steel was a dangerous product to handle; today we feel as confident of cast steel as we do of gray iron, and we have no more failures from cast steel than from gray iron.

[1] Manufacturing executive, Holt Mfg. Co., Peoria, Ill.

The manufacturing processes that go with engineering design are always closely interlocked with it; in fact, engineering design and manufacturing processes are not separable at all; discussion of one leads to discussion of the other.

Fig. 1 shows operations in the timber lands of the Northwest. The timber in which these operations are carried on is extremely high and of large cross-section. Here is an opportunity for a tractor accessory, a saw for cutting the standing timber, that has not yet been developed. The illustration gives an idea of the character of the ground over which the tractors work continually. It is exceedingly hot at times and the radiator of the engine must be protected from the branches of the trees. The cooling capacity of the radiator must be very large so that the guard will not obstruct the air-flow.

This view is merely an example of the general commercial application largely used in the Northwest.

The ability of the tractor to turn readily is shown in Fig. 2. We find no difficulty at the plant in driving the tractor into and loading it on a car. Two 10-ton tractors are put into one car.

Use of Caterpillar Trailers

Fig. 3 shows operation in the Louisiana swamps. Two forms of caterpillar trailer are sometimes used. One is the trailer in which the log lies lengthwise and is supported completely; the other is a short trailer about 6 ft. long, heavily constructed, to which only one end of the log is fastened, the log being dragged out. That type of trailer is used extensively in the Northwest; it would also be a better type of equipment for use in the Louisiana swamps.

I might say that our Southern logging operations can work in another channel. We have a special winch equipment for the tractors. With the winch attachment the operator can approach impassable places, "snake" the log across to a dry loading-place, and then load it. The caterpillar trailer will then be of great help.

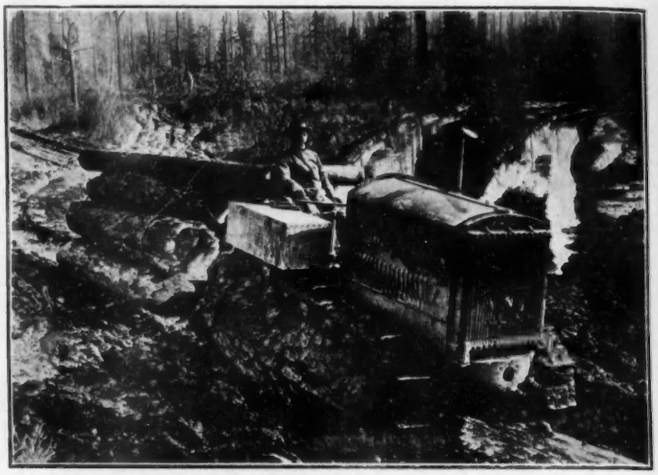

Fig. 3—Logging in Louisiana Swamps
The Tractor in This Instance Is Working in Mud That Clings to the Track

I have rather leaned over backward to keep away from the agricultural side of the subject, even though it was proposed that I present the proposition of cane production in Cuba, I have not treated that as an agricultural operation. If I had shown that view the use of the trailers in the removal of cane would have been very evident; any going of that kind would be easier with caterpillar trailers. Caterpillar trailers, however, are much more costly than wagons; but I think they would be much more durable.

It might be interesting to know that dog-sleds in Alaska are being replaced with 10-ton tractors and caterpillar trailers. They go over snow that the dogs flounder in. The caterpillar trailer apparently has its place. A winch with 600 ft. of line, and powerful enough to handle the equipment, is of great service in an operation of

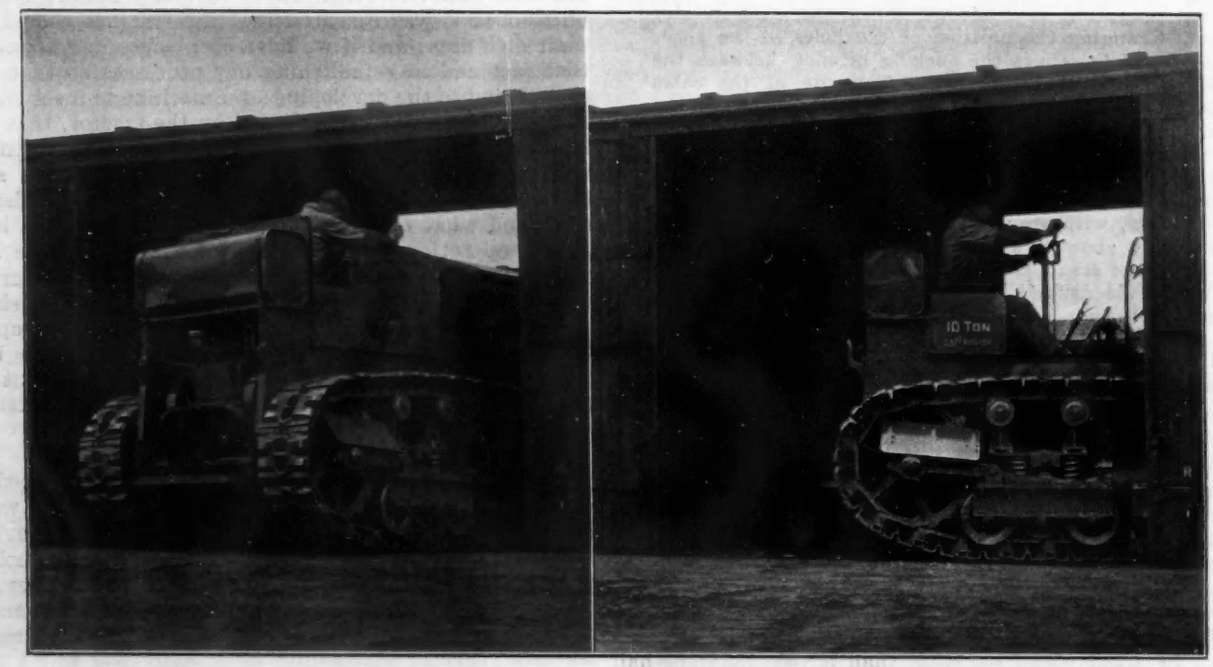

Fig. 2—Loading a Tractor into a Freight Car
On Account of the Short Turning-Radius It Is Possible To Drive a Tractor into the Car as Shown at the Left and then Turn It as Illustrated at the Right. In This Way Two 10-Ton Tractors Can Be Shipped in One Car

that nature, or where logs must be brought out of ravines or carried from one ravine to another.

Operation with Winches

Nearly all the 5-ton tractors that we have shipped into India in the last 2 or 3 years for the British Government are used in logging operations. Both the winch and the tractor are used, depending on the length of the haul. Within 600 ft. the winch is used when they cannot get a full load with a tractor. The equipment in those cases is used in very much the same way that they use donkey-engine equipment.

One agricultural operation that uses winches is the cultivation of very soft lands in Guiana. Two saddle-back winches are used from which the line is played off to the side of the tractor. The tractors parallel the field, one with a winch, the other with a block, or both with winches. They carry the plows between them, approximately 800 ft., cross-plowing the field from the cables and with the winches operating as saddle-backs on the tractor.

Fig. 4—The Tractor at Work in the Snow
This View Gives Some Idea of the Loads Hauled over Snow-Covered Roads and in Some Cases through Drifts and Loose Snow

It has been rather difficult to estimate the average life of the track on a machine operating continuously under those conditions, for the reason that we have been developing the track until recently; but we believe that in a plowing operation of that kind, or in snow logging, the life of the track is almost infinite, that is, the wear is very slight. In Southern logging, I should say that we should get 3000 miles of wear from a track; we have cases in which we have obtained 5000 miles from a track on rather miscellaneous hard going; that is, with heat-treated cast-steel and very carefully made nickel-steel and cast-steel throughout. We are aiming at 5000 miles, except in extremely difficult operations like those of Southern logging and those in rock or sand.

We use a No. 2320 case-hardened nickel-steel pin in the track, bearing against a carburized hardened sleeve of carbon steel. The space-blocks are no longer pressed into the shoe. We found that when we used the rigid spacer, the sprocket in time would cut through the side of the spacer and cut to and possibly sever the pin. Our observations of loose space-blocks in shoes under all sorts of conditions led us to believe that we were wrong in using tight ones; so, more than a year and one-half ago, we changed to the loose or rolling type. The present space-block can be put into the shoe by hand, and the wear is much less.

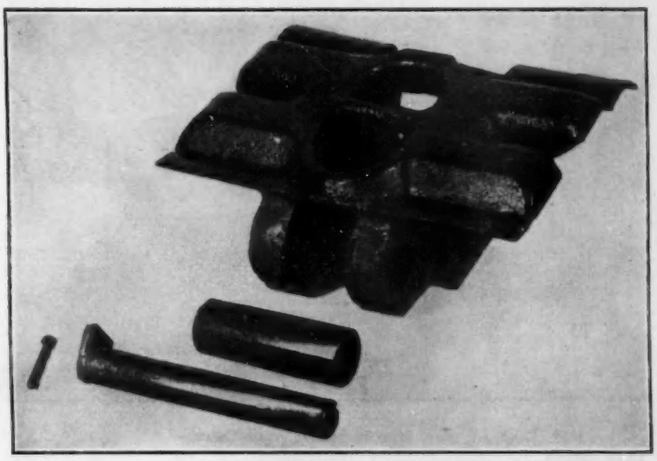

Fig. 5—A Track-Shoe Disassembled into Its Component Parts
The Hole in the Bottom of Track Is Designed To Relieve the Packing of the Snow between the Sprocket and the Track-Shoe. When the Tractor Was First Operated in the Snow, the Snow Would Push Out the Bottom of the Track under the Sprocket Teeth. Opening the Bottom of the Track Has Done Away with This

The No. 2320 case-hardened pin is pressed in under a pressure of not less than 500 lb. per sq. in. It must be a dead-tight fit. If the pin has any movement, it will soon cut itself off in the shoe. The space-block should fit closely to the pin to prevent the ingress of material; and they should both be very hard.

Lubrication of the Track

Oil is sometimes used on the track, but is very bad when operating in sand. In mud, grease in the bearings is good because it emulsifies with the water and will not pick up the dirt. In dry operation, it would absolutely destroy the tractor in no time, because the grease picks up the dry dust, as bread dough would pick up flour, kneads it into a mass and makes an abrasive compound. In this case, oil is the best. If we could be sure that we were to operate continually in mud, we should use grease.

Fig. 4 shows the tractor at work in snow in the lumber fields. Notice the holes in the bottom of track shown in Fig. 5. This change was made approximately 2 years ago; and during the last year we have found out appar-

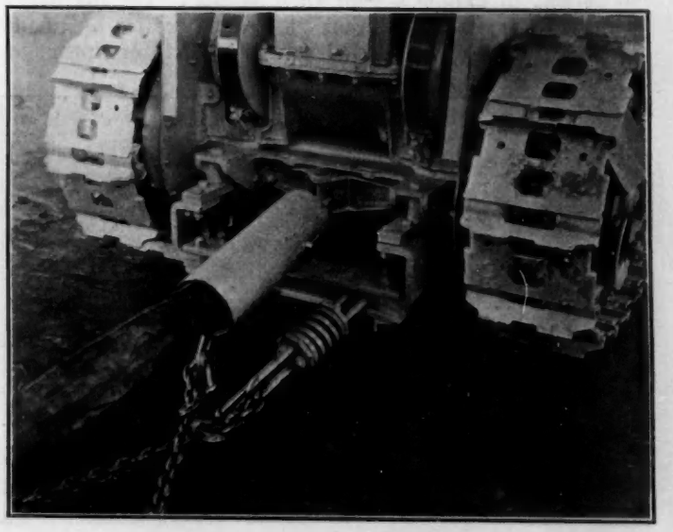

Fig. 6—The Hitch Used for Sleighs
The Sleigh Hitch Used Consists of a Pair of Cross Chains and a Bunting Pole That Fits into a Socket. This Arrangement Enables the Sleighs To Equalize as They Take the Turns

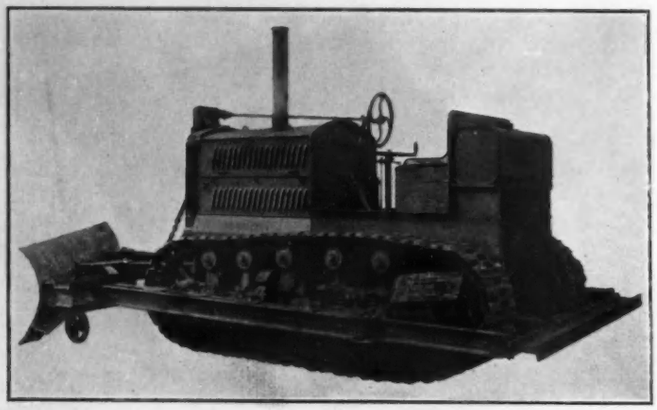

FIG. 7—SIDE-BAR HITCH FOR FRONT-DRIVEN VEHICLES
This Hitch Is Recommended Because All of the Driving Comes from the Drawbar

ently where to put the holes and how to make them to get the best results. The object is to relieve the packing of the snow between the sprocket and the track-shoe. In our first operations in the snow, the snow would push out the bottom of the track under the sprocket teeth. We opened the bottom and since that time have found other very useful applications of this principle.

When two trains of hardwood logs, each with its tractor, come into the main road, they are combined into a single train of sleighs. The road shown is not an ice road, but the ruts are watered occasionally. Logs for making pulp-wood in Canada are hauled over snow; in fact, a train of 10 trailers is taken through snow-drifts, but the wood is lighter; the load is not nearly so heavy as the load shown in the cut. It should interest you to know that the tracks of the tractor are well within the limits of the sleigh ruts; otherwise they would destroy the road because the tractors have grousers that cut the ruts; so the width of the tractor must be considered in the width of the sleigh. The tractor is equipped with a cab for comfort.

There are 50,000 ft. of hardwood, or 300 tons, in the load and, as it goes on into the camp 7 miles away, it is not altogether favored with straight roads or easy grades. The grade, of course, is very flat; it would have to be flat to handle a load such as that. On the other hand, the turns offer great resistance, which is about all that the drawbar will withstand. No interruption of

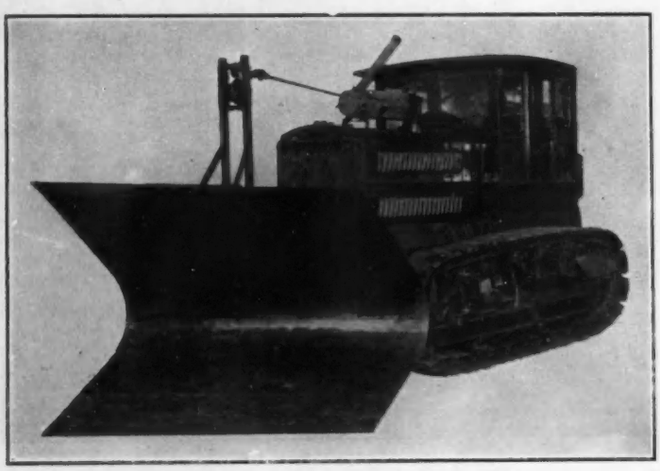

FIG. 8—THE V-TYPE SNOW-PLOW DRIVEN BY A TRACTOR
With This Plow the Snow Is Picked Up, Carried High, Rolled Over and Thrown Over the Bank

the tractor on account of mechanical difficulties was experienced during the period of operation.

The sleigh hitch, shown in Fig. 6, consists of a pair of cross chains and a bunting pole that goes into a socket in the rear sleigh and causes the sleighs to equalize as they take the turns. The character of the sleigh that is used is apparent; it is very simple in construction, the framework being made in the woods.

VARIATION OF SIZE OF CALKS

The calks used differ somewhat, according to the conditions of operation. If we are in very soft snow a pretty deep calk is needed, one that has a heavy grip. On a very highly-finished ice-road, a low sharp calk must be under the rear pin so that, as the track rises, the calk will come out of the ice without tending to rip it up. If it happens to be in the center or in front of the shoe, where it has a prying action as it rises, it will tear the

FIG. 9—A HEAVY ROAD-GRADING OPERATION
The Tractor in This Case Is Hauling a Grader along a Road Fill. The Opening in the Bottom of the Shoe, Illustrated in Fig. 5, Can Be Clearly Seen

road to pieces. I think we have 27 varieties of calk and about 27 different kinds of grouser.

It goes without saying that we experienced considerable difficulty when we put the tractor into the North woods and got it into the snow and on the ice. It seemed that every logging operation required the tractor to operate over the snow when going into the woods, making up the loads and hauling them to make up the trains; then it would have to go over a hard ice road to the cars. Our straight-across grouser was fairly good in the snow, but was unable to penetrate the ice. We developed a grouser that lay across the shoe; the portion at the end of the grouser that extends below the main part is narrower so that the grouser as a whole will penetrate the snow and the narrow ends penetrate the ice. We found that the narrow ends put the shoe on stilts, as it were, and picked up the ice; so a lug was put behind the part of the grouser that penetrated the ice to keep it from penetrating too deeply. That worked satisfactorily. A grouser, to take hold of the ice, must have a support or pressure on the ice immediately behind it. The latest development along that line has been a grouser about $\frac{5}{8}$ to $\frac{3}{4}$ in. high, which extends clear across the shoe. This grouser holds well on the ice and does not break it; with this same little short grouser, when we go out into soft snow, the tractor seems to hold to the full capacity of the tractor.

During last winter, at Escanaba, Mich., in logging operations a short low grouser $\frac{5}{8}$ in. high was used suc-

FIG. 10—ANOTHER EXAMPLE OF THE TRACTOR AS USED ON ROAD WORK
In This Case an Elevating Grader Is Excavating and Loading the Spoil Directly into the Wagon

cessfully in the soft snow in low gear. They hauled 3,000,000 ft. of logs during the winter. The reason that this grouser holds in the snow is that, when pressure is put on the soft snow, the packing begins at the top; it is the hardest at the surface of the snow, settles under the track and gradually decreases from the surface of the snow through the depth of the snow to the ground; if the grouser were longer and penetrated the snow farther, it would get into the soft snow and tear it up considerably, whereas the short grouser penetrates only the part of the snow that is packed hardest and does not get down into the snow far enough to do harm.

It may be noted that we have an ice track in which the grouser is cast into the shoe. It is of chromium high-carbon cast-steel.

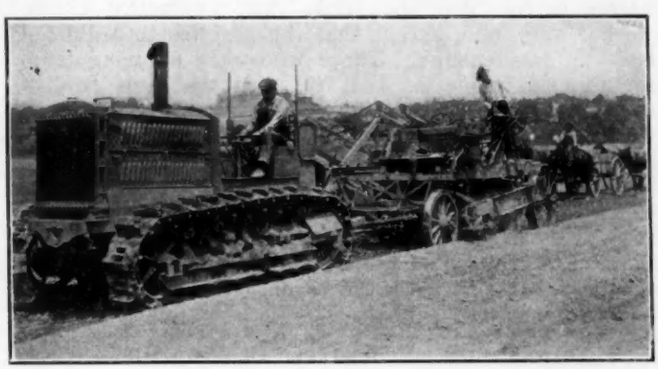

FIG. 11—THE PLOWING SIDE OF AN ELEVATING GRADER
The Speed of the Tractor Must Be Such That the Elevator Conveyor on the Grader Can Gradually Allow the Wagon Being Filled To Draw Ahead, Thus Filling It Completely, and Then Pass on to the Next in Line

The street-cleaning department of New York City uses a flotilla of tractors for removing snow. The side draft of the tractor is a grouser problem. We cannot put a grouser on the tractor that will damage the pavement; yet, with the style of side-plow that is necessary in city streets, the problem of holding the tractor from sliding is very marked. By an open-bottom track that gives some grouser action, by a style of grouser that tends to resist the side-thrust, and by a design of plow blade that gives a better rolling action, the side-thrust has been largely eliminated until now the side-track plow will go along very well, sweeping the snow aside and turning it out of the way. These tractors were in use in New York City 2 years ago at the time of the big blizzard.

The street cleaning department has utilized the fire-engine houses as garages for these machines. At the present time, 52 are in use, I believe. The organization for snow-removal is as adequate as that for fire-fighting. A definite signal-call promptly notifies those who are to assist in case of heavy snow-fall. The operation is highly developed. Since installing that equipment, together with other small tractors and many trucks, New York City has overcome its snow problem; and since that time four or five very heavy snow-falls have occurred.

ROTARY SNOW-PLOWS

A type of rotary snow-plow called the Snow King is being developed by a firm in Minneapolis, which is much more efficient than it would seem to be, for it looks very light and delicate. I believe that there is a fundamental

FIG. 12—TRACTOR AND MANEY SCRAPERS AT WORK IN GRANT PARK, CHICAGO
This Combination Has Replaced Hand Shoveling and the Horse-Drawn Scraper as Means of Grading. The Tractor Illustrated Has the Same Speed in Either Direction So That Continuous Operation Off the Dump Is Made Possible

principle in its application that will eventually develop. It was used very successfully in the North last winter.

We have developed a characteristic hitch for front-driven vehicles, as shown in Fig. 7; and this is used by others who are trying to develop the accessories. We are encouraging the use of this hitch because all the driving comes from the drawbar, as it should.

With a little more power in the front and with somewhat heavier rotors, the plow will move through very large drifts. Its use would be impossible in heavily congested city streets, but on ordinary highways it is very effective. It goes along mile after mile clearing the highway so that it is entirely passable.

Fig. 8 shows an example of the use of a V-type plow

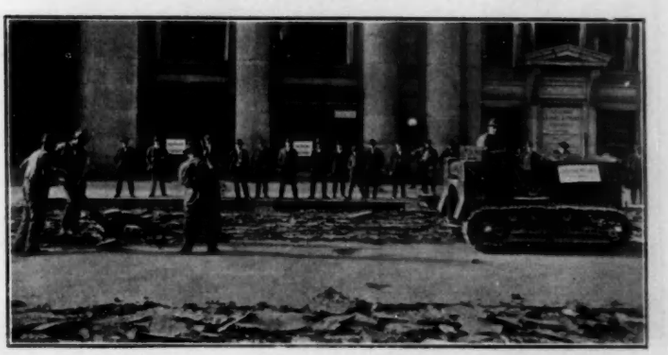

FIG. 13—SCARIFYING ASPHALT PAVEMENT ON A CITY STREET
This Is Another Example of the Versatility of the Tractor. The Old Cement Foundation Can Also Be Torn Up, Thus Giving a Smooth Road-Bed in Front of the Mixer

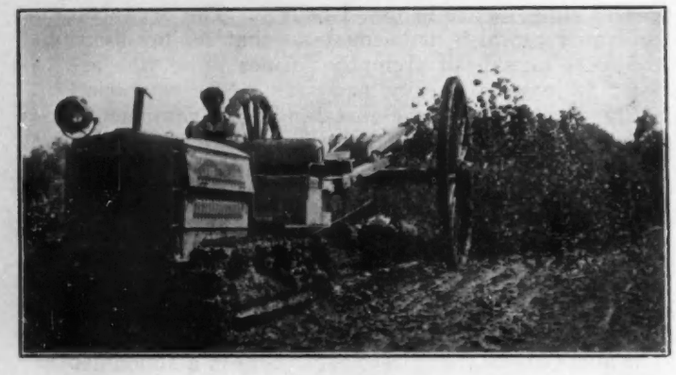

FIG. 14—HELPING TO CORRECT THE FLOW OF THE MISSOURI RIVER
In This Work after the Piles Are Placed Trees Are Drawn into the River and Fastened in Position between the Piles. The River Deposits Soil over These Trees and Cutting of the Bank Stops. The Use of the Open-Bottom Track Illustrated Has Greatly Facilitated Operations

by which the snow is picked up, carried high, rolled over and thrown over the bank.

I believe that an equipment for rotary snow-plows which will give results should have at least a 10-ton tractor back of it, with not less than 120 hp. applied separately to the rotors of the plow itself, the pushing of the plow being taken care of by the tractor. We realize that there is a great and growing demand for snow-plows. New York State now, as you possibly know, is requiring that the highways of the whole State be kept free from snow. I do not know what they will do around Lake Placid, or in the northern Adirondacks, with the equipment that they have, but the work will be done because there is need of it.

The pressure of a 10-ton tractor on a hard road is 6.9 lb. per sq. in. We estimated roughly this morning, that while coming out of the logging woods over the snow, with the track half submerged the area had been extended to a point where the pressure might be about 5 lb. per sq. in. The average pressure of a man's foot is about 7 lb. per sq. in. The narrowness of a man's foot would allow the material to flow out from under it, whereas with the tractor shoe, there is not that tendency, and, of course, the resistance will increase the moment the tractor begins to settle, because the density of the supporting medium is increased.

FIG. 15—PULLING A TRACTOR AND ITS LOAD OUT OF THE MUD
The 10-Ton Tractor Is Equipped with a Winch and a Rehaul Drum for Bringing In the Cable. The Power of the Tractor Engine Is Used To Operate the Winch, the Control Being through the Levers at the Side

APPLICATION TO ROAD GRADING

Fig. 9 shows an application of the tractor to road grading. This gives an idea of the opening of the shoe bottom. In gravelly soils also it is very useful. A feature that is valuable in road-building is the ability to turn at an extremely short radius at normal speed. The equalizing effect of the track is shown. Underneath the front end of the tractor is what is called an equalizing-bar, which allows the front members to move up and down with respect to one another.

Fig. 10 illustrates an important and interesting operation in which an elevating grader is doing the excavating, loading directly into the wagon. Our greatest problem there was to get wagons that would stand the "grief" of tractor haulage. Tractor problems are now largely a matter of accessories. The first elevating-graders would slip and not deliver their loads continuously, so, power was taken from the tractor back to the elevator. With well constructed steel wagons and the fast travel of the tractors carrying the material away, this operation is very effective.

You will notice that the speed of the tractors on the grader and the wagons must be kept so that the elevator-conveyor may gradually retard to the back end of the wagon and, when one wagon has been filled, must move quickly so as to fill the next wagon, as is shown in Fig. 11. The matter of gear-ratios in the transmission is very important.

The Maney scraper, which you probably have seen operating in Grant Park, Chicago, is illustrated in Fig. 12. All the grading work used to be hand-shoveled, or, occasionally, if the slope was not too steep, was done by horses driven over the bank. The equipment shown worked very well, except that the first tractors did not back up fast enough. Those who were securing them for Chicago requested that we give the same reverse speed as forward. The tractors now work back and forth at the same speeds, continually grading off the dump.

In the matter of finishing hard roads, many uses to which the tractor may be put, in addition to grading the road, will be found. The scarifying of old asphalt, as shown in Fig. 13, and the tearing up of old cement, are examples. In this work the roadbed at the head of the mixer is smoothed out.

DIFFICULTIES ENCOUNTERED IN SAND HILLS

A general industrial operation on a sand hill is, I should say, about the limit of the handling of earth after a short haul; it gives self-loading of many scrapers, quick loading, quick dumping and needs only a small train crew. Each of the buckets handles approximately 1 yd.; they handle 5 yd. per trip. It is obvious that only one bucket loads at a time and then elevates. Sometimes two are loading, the second picking up some of the waste from the first bucket. The ability to take the dirt away is measured, of course, by the grading and loading conditions and by the number of scrapers that may be handled in a train.

In correcting the flow of the Missouri River, at Omaha, the river persisted in going where it would at many places; and it became an engineering problem to correct the erratic flow at the minimum expense. The process applied was to drive hollow cement piles hydraulically. The piles have ½-in. pipe-openings in the side. A short section of strong pipe in the entrance to the top of the pile is carried down by ordinary down-spout material, that is, galvanized piping. Hydraulic pressure is applied and the pile is literally washed into place, that

is, the earth underneath is washed out from below as the water comes through the ½-in. pipe in the pile, washing the soil away from the sides of the pile. The pile merely settles into place. Of course, as soon as the hydraulic pressure is removed, the pile becomes firmly imbedded in the soft flowing soil.

After the piles have been planted, some in the river and some on shore, trees are drawn in, as they are found in the district, some having very large butts. Sometimes these trees are drawn into the water where a donkey engine "snakes" them into place between the piles. They are then fastened with butts upstream to a cable. The river immediately begins to retard at this place, deposits soil over the trees and prevents further cutting. It is an interesting operation.

Fig. 14 shows how the trees are hauled to the shore by the tractors. Before we used the open-bottom track, we had to pull the tractors out with others more firmly footed and had great difficulty in getting in. After the open-bottom track was applied, the operations were continuous and were carried on without difficulty.

The tractor will go from high dry table-lands into the very worst of abrasive materials, water, sand and the like. The trees loaded on trailers must be pulled between standing trees, which makes the going very severe. It is one of our hard operations but is so successful that I am satisfied that it will be repeated if conditions warrant this.

Work Among the Oil Wells

We thought the Southern logging was hard going. It is absolutely incomparable with the operation illustrated in Fig. 15. There are no such things as roads. The loads are heavy and are made up of all sorts of equipment, boilers, pumps and pipe; any one who has been in an oil field in the South, in Mexico or in Southern California, will have an idea of the terrible conditions under which the tractors are compelled to operate. They frequently get into such bad mudholes that winches must be used to pull them out.

Fig. 16 indicates the principal purpose of the winch on the tractor, that is, the swabbing of the well itself.

Fig. 16—Swabbing an Oil Well with the Winch
This Is the Principal Operation for Which the Winch Was Placed on the Tractor

Successes follow the winch, judging from the number of repeat-orders we have received.

We believe that the winch is slowly filling a very useful purpose in the industrial application of the tractor. As you will note, we have begun at the rear end of the tractor and have hitched everything on that we thought would work. We have done the same with the front end. We have used even the side of the tractor for a side-haul winch and, possibly, in time, we shall be able to operate upside-down. There may be some part of the tractor from which we have not tried to take off something as yet, but this outline really covers the actual facts in the operation of a tractor for industrial purposes. It is the basis of the largest part of our present work; we are alert to the future and believe very strongly in the opportunities for applying the principles I have endeavored to describe.

ROMAN ROADS

DURING the time of the Roman Empire, the public highways, issuing from the Forum of Rome, transversed Italy, pervaded the provinces and were terminated only by the frontiers of the Empire. If we carefully trace the distance from the wall of the Antonius to Rome, and from thence to Jerusalem, it will be found that the great chain of communication, from the northwest to the southeast point of the empire, was drawn out to the length of 4080 Roman miles. The public roads were accurately divided by milestones and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property. Mountains were perforated, and bold arches thrown over the broadest and most rapid streams.

The middle part of the road, which was raised into a terrace that commanded the adjacent country, consisted of several strata of sand, gravel and cement and was paved with large stones, or, in some places near the capital, with granite. Such was the solid construction of the Roman highways, whose firmness has not entirely yielded to the effort of 15 centuries. They united the subjects of the most distant provinces by an easy and familiar intercourse; but their primary object had been to facilitate the marches of the legions; nor was any country considered as completely subdued till it had been rendered, in all its parts, pervious to the arms and authority of the conqueror. The advantage of receiving the earliest intelligence, and of conveying their orders with celerity, induced the emperors to establish throughout their extensive dominions the regular institution of posts. Houses were erected everywhere at the distance only of 5 or 6 miles; each of them was constantly provided with 40 horses, and by the help of these relays it was easy to travel 100 miles in a day along the Roman roads.—Edward Gibbon.

An Analysis of Costs for 10 Years of Fleet Operation

By R. E. PLIMPTON[1] METROPOLITAN SECTION PAPER

THE discussion following the presentation of this paper at the Metropolitan Section meeting that was held on Feb. 14, 1924, was entirely oral, no written contributions having been received. In accordance with the usual practice, the stenographic report of these remarks has been submitted to the various speakers for their approval and to the author for any additional comment that he cared to make. The corrected discussion, as received, is printed below. An abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the May issue of THE JOURNAL can gather some knowledge of the subjects covered by reading the abstract if they do not wish to take the time to read the complete text.

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

OPERATING costs and their relation to the age of the vehicle have been a subject of controversy for some time. One faction maintains that after a certain indefinite period it is economy to salvage or junk the equipment and replace the vehicles with later uptodate designs. The opposing faction believes that the costs depending on maintenance and operating efficiency can be kept fairly constant. Comparing a motor truck with a locomotive they cite the opinion of railroad officials that when proper running repairs are made locomotives can be maintained continuously in the same service and retain their original earning capacity for many years. When new locomotives are built it is usually for the purpose of replacing types that have become obsolete and the old ones are then relegated to some other branch of the service.

Those who maintain that costs rise with age assert that the motor vehicle is not designed never to wear out; that its maintenance facilities are not comparable with those of a railroad; that each successive overhaul increases in cost because parts either increase in cost or cannot be bought at all and have to be made to order. The question, in the opinion of the author, resolves itself into the case of the vehicle itself: whether it has reached the point where basic improvements are no longer probable and whether first costs will become lower because of greater production.

The most notable development within the last 10 years has been in the price, which is now about the same as it was 10 years ago, notwithstanding the increase in the cost of parts; the weight is about the same and changes in construction have been slight; performance and fuel consumption are also about the same. Maintenance, on the other hand, aided by better inspection, better adjustment and better overhauling, has improved greatly. Based on an accounting system adapted from railroad practice, the cost-keeping methods of the motorbus companies give them a great advantage.

The three factors that may lead to the replacement or the renewal of a complete vehicle are (*a*) physical depreciation, (*b*) obsolescence and (*c*) inadequacy, each of which is discussed. Adequacy is important in order that the type of equipment demanded by the public may be provided. In general, methods of valuation adopted by the regulatory bodies with regard to railroads are applied to motor common-carriers. As an illustration, the course pursued for determining the proper rate of fare-increase to be allowed a motorbus company in Albany is cited.

Graphical charts are given showing the results of double-deck motorbus operation by the Fifth Avenue Coach Co., but these are slightly modified by including taxes. Other charts show the variation of operating costs of 2 and 5-ton gasoline trucks, heavy-duty trucks and 2-ton electric trucks. The yearly variations since 1914 in the costs of gasoline and tires as compared with the wholesale commodity-price index, and those of finished steel as compared with the ratio of the average list price of 5-ton truck parts, are also illustrated by graphs. [Printed in the May, 1924, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN CORNELIUS T. MYERS:—Mr. Plimpton has presented his paper in a manner that should enable those who have anything to say to come right to the point. If each one will give us the benefit of his comments and experience on the point in the paper which to him seems worthy of the most stress, we will gain greatly thereby.

C. W. SATER[2]:—The point that particularly interests me is: What determines the useful life of a truck? The factors that relate to this are physical depreciation, inadequacy and obsolescence. So far as the company I represent can determine, it is not physical depreciation that determines the useful life of a truck because that factor easily can be offset by parts replacement, provided this can be made at no prohibitive cost, and, to date, this is the case with the old trucks we are operating. For example, trucks purchased in 1914, 1915 and 1916 have a repair rate that is just about 50 per cent higher than that on the trucks purchased in 1920, which is the year in which the last 5-ton trucks were purchased. In spite of this, the operating cost per mile is 11 per cent less in the case of the old trucks than the new ones, simply because the rate of depreciation per mile has dropped 70 per cent on the old trucks. Since the trucks purchased from 1914 to 1916 are giving approximately the same performance the new trucks give, the factor of inadequacy has not concerned us as yet. As compared with the year 1919, which was the first year that we kept records, the performance of the old trucks last year represents a 10-per cent increase in mileage, a 9-per cent increase in tonnage and a 7-per cent increase in total cost per truck per day in service. The increase in cost is due to an increase in the fixed-cost items, such as insurance, license, rent and wages, over which we had little control; while the operating-cost items of gasoline, oil, repairs, tires and depreciation, over which we had con-

[1] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.

[2] M.S.A.E.—Supervisor of transportation, Great Atlantic & Pacific Tea Co., Jersey City, N. J.

siderable control, showed a decrease of about 41 per cent. The outstanding factor that determines the useful life of a truck for us is obsolescence, but, in view of our experience to date, we do not feel that this point has been reached in the case of the old trucks. While refinements that permit more economical operation have been made in the new trucks, the economies effected have not been sufficient to warrant the retirement of the older trucks. The question of what determines the useful life of a truck has been given great consideration by the company I represent.

CHAIRMAN MYERS:—How about this point of depreciation? Here is a statement to the effect that the older trucks are running at lower costs than the newer ones, due evidently to the fact that they have largely been written-off in previous years and stand at a very low figure on the books. Of course, writing-off values is an arbitrary procedure; still, we all have to make up our minds as to how rapidly these trucks should be written-off, and the write-off on the new ones, of course, should be based to a considerable extent on our experience in the past. If we have to write-off the new trucks at a high figure and can keep the old trucks in such shape that they can actually beat the delivery costs on new ones, it is a thing that certainly merits attention and discussion.

S. H. WOODS[3]:—As to whether operating costs remain stationary throughout the life of the vehicle or increase from year to year, much depends on the system of accounting employed. Operating cost must include depreciation, and this includes a certain percentage representing obsolescence. The balance represents physical deterioration, of which a large percentage will be offset by the repairs made to maintain the vehicle in first-class condition. This is merely the working out of the well-known principle whereby depreciation and repairs offset each other. In other words, if the vehicle is maintained in first-class condition, a certain considerable percentage of the cost of maintenance can be taken from the depreciation charge, although this would not be permissible if the vehicle were not so well kept-up.

The character of the management of a truck-operating enterprise is of the utmost importance. When the management is such as to build up a feeling of pride in the appearance, efficiency and reliability of the fleet throughout the operating and maintenance organization, the results are more to be reflected in reduced operating and maintenance costs and increased vehicle-life. I have seen so many examples of this that I have not the slightest hesitancy in making this statement. Also, regarding the management, it is well to mention inspection and lubrication, these being the items that must have the constant and conscientious attention of the maintenance force. In this connection I refer to railroad practice in which thorough inspection at frequent intervals has been the rule for years. With the right espirit de corps in the organization, proper attention to these matters will follow naturally.

In summarizing developments of the last 10 years, some of the equipment that has been developed during this period to facilitate maintenance should not be overlooked. Notable among these developments are the pressure-gun system of chassis lubrication and the air-filter. The former greatly reduces the length of time necessary for lubricating the vehicle chassis. The air-filter, by preventing the contamination of the engine oil by foreign material, makes it possible to run an engine for a greater length of time without risk of excessive wear, because a much higher percentage of crankcase-oil dilution can be permitted if the oil is kept clean.

CHAIRMAN MYERS:—Mr. Plimpton made some statements in regard to the state of the design of trucks, pointing out the fact that the truck purchased today bears a very marked resemblance to the truck of similar type purchased 4 or 5 years ago; not only in its general dimensions, but actually in performance. We ought to hear from some of the men who are operating delivery vehicles in the city. Prior to a meeting of the Retail Delivery Association last year, a number of men operating such vehicles asked me why the vehicles could not be improved to a very considerable extent. That is a subject to which all engineers will listen with great attention. I believe also that the manufacturers would be only too glad to give points pro and con on that subject.

JOSEPH MCLAUGHLIN[4]:—As to determining the life of a truck, no one as yet has run a truck out and kept records on trucks long enough to find out how long a truck should last; for instance, no one has records for the operation of a truck for as long as 15 years and, therefore, truck life has not been determined. If a truck has been running since 1914 and is in better shape than it was then, it may need to be run 10 years more to reach the point where it should be disposed of. There is no depreciation if a truck is kept-up.

CHAIRMAN MYERS:—In other words, your experience up to the present time is that the vehicles are remarkably durable, and you have not yet found out how long they will last.

MR. MCLAUGHLIN:—Our experience is the same as that of Mr. Sater. After 5 years of running and keeping a complete record, our vehicles ran 11.75 per cent more efficiently on gasoline than they did the first year we bought them, and 235 per cent more efficiently on oil than they did the first year.

CHAIRMAN MYERS:—What has been your experience with regard to the wearing-out of parts? What parts gave you the most trouble?

MR. MCLAUGHLIN:—All parts give trouble; but the more attention we give them and the better they are lubricated, the longer they will last. Doubtless, certain parts can be improved upon.

CHAIRMAN MYERS:—Do you find, for instance, that this very notable decrease in your oil consumption has caused any increase in the wear of the engine parts, or vice versa?

MR. MCLAUGHLIN:—The wear on the engine parts is less, by far, due partly to lightening reciprocating parts and using an oil suited to the conditions.

CHAIRMAN MYERS:—How about other parts of your trucks?

MR. MCLAUGHLIN:—Every design of truck has weak points. Each engineer has his own ideas; if he uses a certain type of construction, he will not change to use some other person's design. Certain passenger-cars have rear-end constructions that will last from 10 to 20 times longer than those of others, and yet the engineers of the latter will not put in the better type of construction but retain their designs and let them break down.

ROBERT HEBRON[5]:—Will you make a comparison between the present-day steam-engine and the gasoline engine?

MR. MCLAUGHLIN:—Steam does not enter into the problem at present.

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[3] M.S.A.E.—Experimental engineer, International Motor Co., New York City.

[4] Superintendent of motive power, The Eleto Co., New York City.

[5] Supervisor of motor vehicles, R. H. Macy & Co., New York City.

JOHN MCLACHLAN[6]:—Regarding the performance of trucks as they become older, as to the number of miles obtained per gallon of gasoline and per gallon of oil, my experience is that a motor vehicle gets older in every sense of the word and becomes more expensive to operate. Gasoline efficiency may remain constant throughout the life of the vehicle. Oil consumption can be considered on the same basis. The life of a piece of mechanism is determined by the number of vibratory movements it will withstand. A motor vehicle is subjected to many vibrations and, every minute a truck is being operated, its life is surely being shortened. We have made a very close study of the performance of a motor vehicle in commercial use. It has been found that a time arrives when considerable thought and study should be given to whether the vehicle should be operated longer or replaced. Considering the value of uninterrupted service, we have found that it is to our advantage to dispose of the old vehicle and replace it with a new one.

MR. HEBRON:—If a motor vehicle is still on the market and is not obsolete, and the cost of a general overhaul to put it into first-class condition again were approximately $600, would it be economical to relegate the vehicle to the junk-heap and pay $2,500 for a vehicle to replace it?

CHAIRMAN MYERS:—Will Mr. Hebron state his views on that?

MR HEBRON:—I say that it would not be economical to junk the vehicle.

MR. MCLACHLAN:—It depends wholly upon the service that will be obtained from that vehicle after spending $600 on it. If 12 to 18 months of uninterrupted service can be obtained from it then, it would not be advisable to dispose of it. It is very doubtful if a 2-ton truck can be repaired for $600 when it needs a thorough overhauling. I do not think it can be done. Our fleet is made up of gasoline-driven and electric-driven vehicles; 80 per cent of the former and 20 per cent of the latter.

MR. HEBRON:—We have proved that we can put a truck into first-class shape after giving it 10 or 11 years of service. That may seem an extravagant claim, but it is an absolute fact. After one of our trucks of a certain make has been in service for 5 years, we use average methods of repair and inspection and keep it on the road until the end of 8 or 9 years, before buying a brand new truck.

CHAIRMAN MYERS:—At about what cost per year?

MR. HEBRON:—The cost per year is the same as for the other vehicles, including the daily inspections and everything that concerns the physical make-up. On the average, when a 2-ton truck comes to the point where it must be overhauled, it costs about $600 to overhaul it.

V. E. KEENAN[7]:—I agree with Mr. McLaughlin, but I must disagree with Mr. McLachlan. Assuming that a motor-vehicle chassis is maintained properly, I believe it should never wear out. We have this fact very forcefully brought out in bus maintenance; buses are running from 40,000 to 60,000 miles in 1 year, which is as much mileage as was commonly believed to constitute the normal useful life of a truck only a few years ago. It is not so much a question of when to retire a vehicle as it is what type and kind of vehicle to buy. In our fleet at Providence, R. I., we have five different types of motor-vehicle chassis in bus service and, after a period of time, we find a vast difference in operating costs between the various groups. Of the costs directly chargeable to mechanical units, the range between the most economical and the most expensive is 179.5 per cent. All these vehicles are doing practically the same work; their loads are fixed, and their operating conditions are identical. Here again it is not a question of when to retire the most expensive unit, but rather to ask why this unit was purchased. The success of more than one enterprise using motor vehicles rests on selecting a vehicle properly at the outset.

Regarding Mr. Plimpton's reference to standardized methods of accounting, we are all talking a different language unless we have a basic method of comparing costs. Undoubtedly, many of us have met the bus operator, invariably an independent, who will make the bold statement that he is running his buses for 15 cents per mile. But that cannot be done. Most of the managers of the railroads throughout this Country are talking costs in a universal language. They have been doing this for years because of the legal requirements surrounding the filing of statements with the various Utilities Commissions and with the Interstate Commerce Commission. I think that the operators of large truck-fleets should be quick to support any move that follows a similar line.

With reference to charging off certain units over arbitrary periods rather than charging off the complete vehicle, Mr. Plimpton's suggestion is worthy of thorough consideration. If a vehicle, designed properly in the first place, is a proper one for a given kind of work, and proper maintenance methods are followed, there should be no limit to its life; consequently, it is logical to establish some fixed time, based on experience, as a suitable period for the useful life of the various units.

As better management of fleet operations becomes apparent, we are all learning more about the maintenance problem. More able men are entering the maintenance side of the business. We find shop production-methods utilized in service-stations and large-fleet garages almost everywhere it is feasible to do this. Maintenance methods have improved. They have gone through more rapid cycles than have any basic changes in the design of the chassis. I believe that the maintenance problem will work itself out with better methods. The useful life of all vehicles cared for by these methods will be extended.

My theory is that engineers and designers of equipment should consider more than anything else the question of accessibility. Certain points on all chassis baffle the ingenuity of all maintenance methods, chiefly because of inaccessibility. On a certain chassis it is necessary to remove the front cross-member of the frame to change a starting-crank jaw. Engineers should be directly interested in all these things, as well as in the questions regarding the useful life of the entire vehicle and when to sell the customer a new one.

CHAIRMAN MYERS:—I would like to make this meeting of as much benefit as possible to those who are designing cars, as well as to those who are operating cars. There is just as much ambition on the part of the man designing the job to turn out a good serviceable long-lived vehicle as there is on the part of the user to get such a vehicle. There has been far too little cooperation between those who use and those who build, up to the present time; in fact, the keynote of all our meetings here has been to try to present the user's viewpoint. The Metropolitan district is the center of the greatest aggregation of motor-vehicle equipment in the world, and we are able to bring out at our meetings the points that are of vital interest to those who use trucks, buses, passenger cars or anything in the automotive field. Those

[6] M.S.A.E.—Supervisor of motor vehicles, New York Telephone Co., New York City.

[7] United Electric Railway Co., Providence, R. I.

things we wish to present strongly to those who build the product.

K. G. MARTIN[8]:—The point brought up about the replacement of vehicles at the end of a certain period interests me. Today, in shipbuilding or locomotive building, the higher efficiency secured by modern design and construction makes it economically profitable to scrap ships and locomotives after relatively short periods. That is a little different from the situation with the motor vehicle. We are still working with gasoline and with oil for a lubricant. You must remember that in other transportation fields they shifted from coal to oil. If we shift from gasoline to some other fluid or to a solid fuel for purposes of propelling the vehicle, and to some other method of lubrication, we may arrive at a time when we can afford to scrap a large proportion of our motor vehicles, or adopt such fuel and such lubricating method by using auxiliary devices.

DAVID BEECROFT[9]:—Our thought is to reduce the cost of transportation. The problem is that of moving commodities or persons over a gi· en distance at the lowest possible cost.

An important point was made by Mr. Keenan when he said that it is not a question of when to retire the vehicle but of what vehicle to buy. I have looked over reports from more than 8000 operators of motor vehicles throughout this Country in the last year. They show the makes of vehicle operated. The number of vehicles operated by each firm ranges from 3 to almost 5000. Many firms operating four vehicles have three different makes of vehicle. When asked why they bought so many makes of vehicle, the reason assigned was that of confusion created in their minds by the people who presented these vehicles for sale. Solely because of that, a rather serious transportation situation is before us, and it will be a few years yet before the matter will be remedied.

I regret that more designers of motor vehicles are not present to hear the criticism of their vehicles. I encountered an instance recently of an engineer putting a certain kind of rear-end construction on his vehicle for no reason other than that he designed some feature of it and had lost sight of everything else. We have seen companies practically go into liquidation because of the obstinacy of the engineer or someone else connected with the firm. I believe that the solution of this situation will be determined very largely by the gentlemen now present and the thousands of operators whom they represent. They will decide the question of depreciation. They are deciding the question of buying. Mr. McLaughlin suggested that cost figures for a period of 15 years are desirable; but when good cost figures for a period of from 8 to 10 years are available, a difference in the buying will be seen.

The majority here agree that depreciation depends very largely upon the inspection and the maintenance systems. Lack of efficient inspection is causing heavy transportation costs today. One fleet of nearly 100 vehicles in this Country is averaging 6000 miles per vehicle with only one stop caused by some mechanical trouble; in other words, each vehicle in that fleet is making the equivalent of a trip from New York City to San Francisco and back, with only one forced stop. That fleet is thoroughly inspected every night; it is given a general overhaul every 2500 miles; and it is given a complete overhaul at the end of each year. But, in that fleet, the unit-repair system is used. If engines should be taken out, or gearboxes or clutches or rear-ends, that is done. That fleet has 98 per cent of its vehicles in operation; 2 per cent of them are out of service undergoing general inspection or complete overhaul. That can be attributed largely to a thorough system of inspection; it is not only an inspection in the garage or the service-station at night, but one made by inspectors who are on the streets and highways during the day.

The influence of the personal element in reducing the cost of transportation has not been stressed sufficiently; that is, working with those who have the vehicle in hand so that drivers do their best while they are on duty. A great deal is being accomplished in this connection by many of the operators of large fleets, but this is only a beginning. The truck driver must be brought up to a standard that will produce in him an appreciation of his job. The drivers' meetings that are being held are a help. Operators who allow their drivers to carry the driver's name on the vehicle while it is in use are accomplishing much. Several operators of large fleets and some operators of small ones have placed their employes on a bonus basis; the bonus applies not alone to the drivers but also to the mechanics in the shop and to the inspectors, because these three classes of workmen have a close relationship. Good results are being attained. In other organizations the drivers are participating in the profits after a certain amount has been set aside to meet a 5 or 6-per cent dividend on the preferred stock, with good results.

Reduction of the cost of transportation does not resolve itself entirely into a question of when a vehicle is to be retired. The retirement of a vehicle depends upon its design, the system of inspection, the driver, the system of maintenance, the character of the streets and highways traveled and the kind of business in which the vehicle is engaged. The main consideration is that we get a correct perspective of all the factors that enter into the cost of transportation. After that, we must give the personal factor an important place, because the motor truck or the motorbus is merely a tool to accomplish a certain end. The efficiency that we get out of that tool is a measure of the good sense in the organization that is back of it, in regard to purchase at the start, operation and maintenance.

QUESTION:—Were any two companies using the same system of accounting?

R. E. PLIMPTON:—So far as truck fleets are concerned, I have never known of any two companies using the same accounting system. Even in cases in which a certain degree of standardization exists, for instance, those of electric railways that have adopted a form of the Interstate Commerce Commission classification, I would not say that any two companies are using the same accounting system. Doubt in regard to some of the fundamentals still persists; that is, just what ledger accounts should be used. That remains to be tested by experience of the electric-railway companies.

QUESTION:—What recommendations has Mr. Plimpton to offer that will be useful to the operator?

MR. PLIMPTON:—The need is great for some standardized system so that the truck operator, particularly, can compare the results of his operations and make sure that the comparison extends back far enough into original sources to be worth something. Another point is that the manufacturers should participate to a greater extent than they have participated heretofore, and either develop model service-stations or keep working with large truck-fleet users to improve their operating practices. Some makers are beginning to do this, but much more of it ought to be done.

[8] A.S.A.E.—Account executive, Rickard & Co., New York City.
[9] M.S.A.E.—General manager of *Motor Transport*, New York City.

J. F. WINCHESTER[10]:—Mr. Beecroft mentioned a fleet owner who operates 100 trucks and says he only loses 2 per cent of his time. How many hours a year does this operator spend in inspecting his vehicles?

MR. BEECROFT:—I cannot state the amount of inspection time on each vehicle per day. At the end of from 2000 to 2500 miles, the inspection time averages 6 hr. As many as eight different groups of workmen may be operating during that period, on the engine, the clutch, the brakes, the gearbox, the electrical equipment, the body and the like.

MR. SATER:—In the drivers' bonus system of The Great Atlantic & Pacific Tea Co. the plan is to pay the drivers on the basis of their performance; that is, according to the miles traveled, the tonnage handled and the earnings. At the end of a predetermined mileage life, the truck becomes the property of the driver. The plan has been in operation about 5 years. During that time only 5 out of about 134 drivers have been lost. At our least efficient point the efficiency has been increased about 43 per cent, and at our most efficient point the efficiency has remained about the same. Without any doubt the paying of considerable attention to the personal element by the transportation organization of our company has contributed very largely to whatever success we have had. We feel that good personnel and efficient maintenance are the two factors that make for efficient and economical fleet operation.

C. O. BECH[11]:—Concerning the upkeep of motor-vehicle equipment today compared with that of some years ago, one of the chief reasons for the lower upkeep today is the way in which our men, drivers, inspectors and mechanics, have been trained to handle the equipment. Undoubtedly, the cost of operation of the general average of trucks purchased today is lower than that of trucks placed in service some years ago. It is difficult sometimes to decide what to buy on account of the many inducements that are offered and the many claims made as to improvements in construction. We have to judge for ourselves when we buy new trucks because, due to changes in construction, we have no other vehicle to compare them with.

If we could take some of the trucks that have been in service for 3 or 4 years, on which we have a record of the cost of operation, and then pick the best performers out of that lot and buy some more of the same kind, we would consider ourselves fortunate. However, when we are ready to buy, we find that improvements have been made and are advised to buy practically a new unit. That, of course, increases service difficulties; we have to stock more parts; we have to train our men to take care of the new units; and new troubles develop, which the men did not know anything about before. I believe that is one of the big handicaps today; we get too many models and makes of truck into service. It is impossible to standardize because, if we did, it might be that the performance of some trucks of a better class would be left out of consideration. We have to have three to five different makes to permit the selection of the best make for our general use.

Concerning accounting, while it may be that various forms are in use, I find it remarkable how closely all the various figures compare with one another as to cost of operation per ton or per mile. That applies to the general average, for size as well as for mileage. Regarding the bonus proposition for drivers, our business does not permit us to give such a scheme much thought. Our drivers are perhaps more responsible for soliciting business than they are for driving a truck. If we find a man who is a particularly bad truck operator and the costs are rather high, but he is a particularly good solicitor, it may be advisable to let him continue to operate the truck so long as he sells the goods.

We try to stimulate the men by calling attention to the cost of operation of particular trucks, keeping a man on the same truck. In suitable cases we call attention to the fact that a man has operated a truck for a certain long period and that its upkeep cost has been very low; or that someone else has operated another truck of the same type and size and covered approximately the same mileage and done the same work, but that the upkeep cost has been particularly high. That brings out a competitive spirit between the men and helps us to attain better performance.

FRANK R. FAGEOL[12]:—To get a proper perspective, the operation of a motor vehicle probably should be divided into its many elements. Of these, perhaps the main elements are: purchase price, mechanical maintenance, driver-wage, garaging, cleaning and general superintendence. It seems logical that the proper time at which to replace a motor vehicle, barring obsolescence having set in, is when the cost of mechanical maintenance doubles on the part of the purchase price that represents depreciation. This can be figured definitely at a certain number of cents per mile over some predicated normal life. In other words, in motorbus operation, which we recently have been studying more closely than anything else, we find that purchase price represents from 12 to 14 per cent of total operating cost. We find, incidentally, that mechanical maintenance has about the same relation.

MR. PLIMPTON:—Referring to previous remarks on the matter of deciding wisely upon what make of vehicle to buy, I admit that this is important. But, formerly, if a salesman could not sell one truck during his first 6 months of service, he was discharged. I will assume that it takes a truck operator 6 months to decide what he will buy, and yet we have heard in this discussion that we operate the vehicle anywhere from 7 to 20 years after we get it. So, I submit that, while the 6 months may not be a direct or fair comparison with the 7 to 20 years, it emphasizes the importance of reducing costs and running the fleet right after the truck is bought.

Taking the discussion here as a whole, the thing that stands out is the many signs of progress in the business of automotive transportation. Bus, taxicab, truck, all of these have now reached the point where their application deserves the best endeavors of automotive engineers.

[10] M.S.A.E.—Supervisor of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

[11] M.S.A.E.—Superintendent of motor equipment transportation, Texas Co., New York City.

[12] A.S.A.E.—General manager, Fageol Motors Co., Oakland, Cal.

Air-Springs and the Measurement of Automobile Riding-Quality

By JOHN J. MCELROY[1]

DETROIT SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

AN air-spring and a steel-spring combination has a characteristic load-curve that allows maximum flexibility in the general working-range of the axle yet has an increasing resistance to dissipate large shock-loads. By varying the compression volume in the air-spring, the load curve of the combination can be made more flexible or stiffer as occasion demands. Tests show that the steel-spring vibration alone had a duration of 5½ sec. with a period of 87.2 vibrations per min.; the combination, a 3-sec. duration with 60 vibrations per min.

Field tests of front-axle movement were made, the test apparatus for these and other tests being illustrated and explained. The maximum axle-movement either above or below the normal line is increased when using air-springs, and the subsequent rebound shows more action on the underside of the normal line, the general tendency of the air-springs being to float the chassis on a slightly higher plane at the time of rebound. A reduction in the vibration period and its duration with increased up-and-down axle-travel was indicated also. An axle-movement recorder was then developed and used in tests made over an average rough country-road test-course.

Total up-and-down axle-amplitude is increased about 28 per cent by the use of air-springs and the amplitude above the normal line is reduced about 29 per cent; but the total amplitude below the normal line is increased 105 per cent, thus pushing the theoretical normal line or axis of the axle vibration away from the chassis under running conditions. This tendency to float allows the air-spring combination to have slightly less axle-clearance at rest than would be provided for the steel springs alone. The net reduction of axle-vibration duration over a period of time, is approximately 16 per cent or say a reduction in axle movement of 5 vibrations per sec. without air-springs to 4.12 vibrations per sec. with them. This reduction is a natural function and still leaves the axle free and flexible in both directions, yet capable of very fast action in absorbing shocks and making contact with the ground in depressions. Hence, the general effect is to smooth out the body line of travel and reduce the objectionable vibrations in the chassis and in the body.

Testing for riding quality involves two constant factors, the course and the testing instrument. The speed and the ability of the driver to retrace his course in identically the same path at identically the same speed are the variables. The instrument used for measuring riding quality is illustrated, and the results obtained are discussed.

Air-springs have been in common use on automobiles for the past 10 years, but very little technical information concerning them has been published. This paper treats the subject of air-springs from an engineering standpoint.

THE present air-spring suspension is a typical counter-spring, and produces better riding quality due to the inherent characteristics of its combined spring-action. The general principles of the counter-spring are fairly well known, and a number of supplementary coil-spring shock-absorbers are on the market; they are used as auxiliary members of the spring-suspensions. Some manufacturers of foreign cars have gone so far as to interpose as standard equipment an auxiliary coil-spring between the frame and each end of the steel spring. Unquestionably, the auxiliary spring so mounted absorbs the smaller vibrations and reduces the acceleration of the free end of the steel spring, and its value is generally a plus quantity in the direction of more comfortable riding. Ethelbert Favary has stated that the ordinary coil-spring used in practice has a very much higher vibration period than have leaf springs that carry the same amount of load and that, in a poor combination, the efficiency of a counter-spring suspension is negligible. I agree with him. The ordinary coil-spring must have considerable free length to form a satisfactory combination with the leaf spring but, if care is taken in the design throughout, improvement in riding quality can be obtained.

LOAD CURVES

In addition to the typical counter-spring action, the air-spring suspension has a characteristic load-curve that is entirely different from that of the steel spring and coil suspension. This is due to the fact that the compression or load curve of the air-spring is practically isothermal, and this characteristic is felt in the load curve of the combination. Fig. 1, at the left, is a dia-

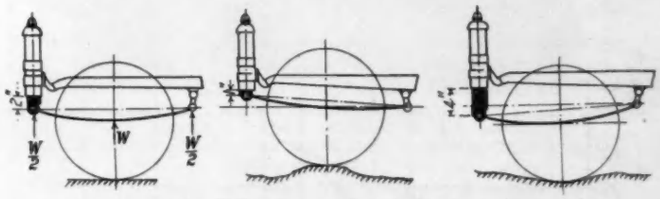


FIG. 1—DIAGRAMMATIC DRAWING SHOWING THE COMBINED ACTION OF A TYPICAL AIR-STEEL SPRING-SUSPENSION

The Views from Left to Right Illustrate the Air-Spring at Rest in Its Mid Position, the Compressed Position when Passing over an Obstruction and the Position Assumed by the Spring when the Wheel Drops into a Hole. The Following Table Gives the Data Relating to the Suspension

Position of Air-Spring	At Rest Mid	Compression 1 In. Compressed	Extension 2 In. Extension
Effect at Axle, in.	0	0.50	1
Steel-Spring Camber, in.	2.00	1.40	2.58
Total Load, lb.	400	640	170
Combined Axle Movement, in.	0	1.10 Above Normal	1.58 Below Normal
Spring Scale, lb.	190	240	145

[1] M.S.A.E.—Chief engineer, Westinghouse Air Spring Co., New Haven, Conn.

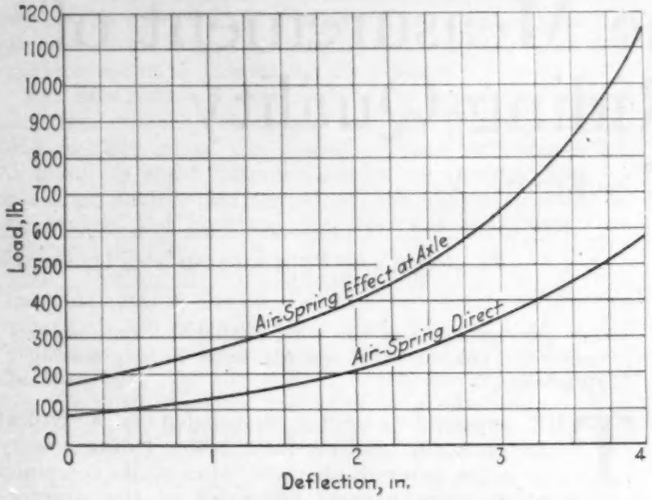


FIG. 2—CHARACTERISTIC LOAD-CURVE OF THE AIR-SPRING
The Lower Curve Is the Typical Compression Curve of an Air-Spring Alone; the Upper Curve Shows the Same Air-Spring Effect at the Axle If a Rigid Beam Was Used instead of the Steel Spring

grammatic drawing showing the combined action of the air-spring and the steel spring. The load on the air-spring, considering the axle in the middle of the steel spring, is one-half the load at the axle. In Fig. 1 we have illustrated a 400-lb. scale steel-spring which is compressed 1 in. under load. An additional load will compress both the air and the steel spring. If the air-spring is compressed 1 in., the axle moves up ½ in. and, if it takes 240 lb. at the axle to compress the air-spring 1 in., it will compress the steel spring to the extent of 240 lb. or 0.6 in. This results in a total upward axle movement of 1.10 in. for an additional applied load of 240 lb. A 400-lb. steel-spring alone would need to have a 440-lb. additional load to compress it 1.10 in. The central and right views in Fig. 1 show the combined spring action when passing over a bump and going into a depression.

The lower curve in Fig. 2 is the typical compression-curve of an air-spring. The upper curve is the air-spring compression-curve as at the axle, if we consider the steel spring a rigid member. Fig. 3 is the ordinary

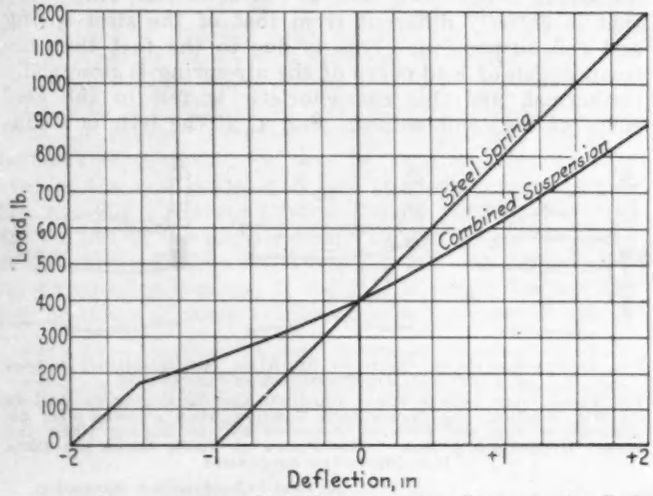


FIG. 3—CHARACTERISTIC LOAD-CURVE OF THE COMBINED AIR-STEEL SPRING-SUSPENSION CONTRASTED WITH THE STRAIGHT-LINE LOAD-CURVE OF THE SAME STEEL SPRING THAT IS USED IN THE COMBINED SUSPENSION
It Should Be Noted in This Connection That the Load-Curve of the Combination Has an Ever-Changing Scale That Increases in Stiffness as the Load or Shock Increases and Its Minimum Scale Is That of the Steel Spring, This Occurring Only When the Air-Spring Has Reached the Full Extent of Its Stroke

straight-line load-curve of the spring, contrasted with the load curve of the air-spring combination. The load curve of the combination has an ever-changing scale that increases in stiffness as the load or shock increases, and its maximum scale is that of the steel spring, this occurring only when the air-spring has reached the full extent of its stroke. If the air-spring is designed so that it is impossible to complete its full working-stroke, the spring scale of the combination is always under that of the steel spring alone.

The combination suspension has a long range and breaks off abruptly at the bottom of the curve into steel-spring action alone; the scale then instantly changes to that of the steel spring. This occurs when the air-spring has reached the end of its downward stroke. The air-spring and steel-spring combination has a characteristic load-curve that allows maximum flexibility in the general working-range of the axle, yet has an increasing resistance to dissipate large shock-loads. By varying the compression volume in the air-spring, the load-curve of the combination can be made more flexible or stiffer,

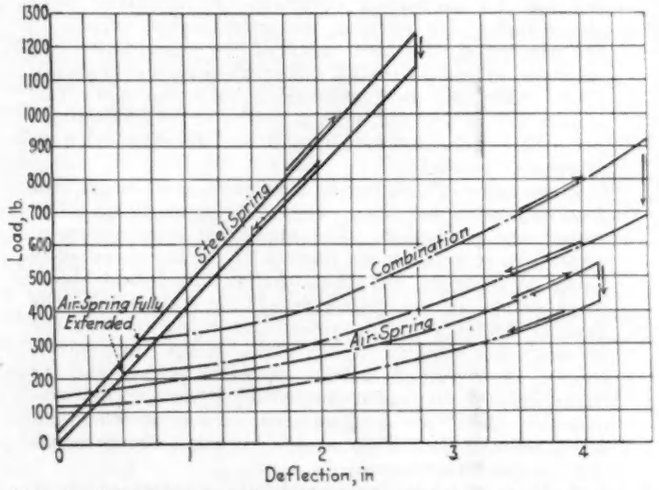


FIG. 4—CHARACTERISTIC LOAD-CURVES SHOWING THE FRICTION OF BOTH THE AIR AND THE STEEL SPRING ALONE AND IN COMBINATION
These Curves Were Obtained as the Result of a Laboratory Test on a 3-In. Direct-Acting Air-Spring in Combination with a Standard Dodge Front-Spring. This Friction Is Static, Test Readings Being Made at 1-Hr. Intervals. The Actual Sliding Friction of the Air-Spring Alone Is Approximately One-Tenth of the Static Friction

as occasion demands. The proper combination always will give remarkable results.

Fig. 4 shows the results of a laboratory test on a 3-in. direct-acting spring working with a standard Dodge front steel-spring. The Dodge spring has a 36-in. overall length, and the axle is located 15 in. back from the front eye, leaving the rear half 21 in. long. The vibration period and the duration of the vibrations are reduced materially. This damping effect is shown graphically in Fig. 5, which is a comparison of the vibration period of a leaf spring with that of the air-spring combination. The heavy-line curve in the upper portion shows the vibration of the steel spring alone as recorded on the moving paper. The air-spring and steel-spring combination under the same test is shown in the lower portion of Fig. 5. In this latter case the air-spring movement and the combined movement of both the air-spring and steel spring at the center or axle position were recorded simultaneously on moving paper; and, by making proper corrections, the effective movement of the air-spring at the axle was plotted. The shaded area represents the work of the air-spring at the axle. The difference between the combined movement and the air-

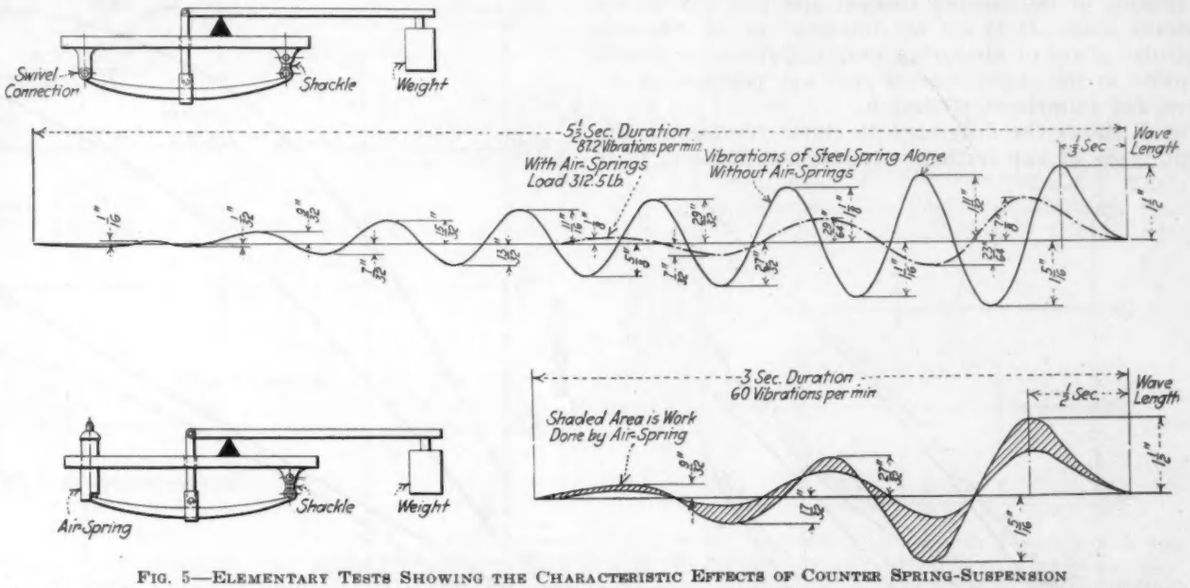


FIG. 5—ELEMENTARY TESTS SHOWING THE CHARACTERISTIC EFFECTS OF COUNTER SPRING-SUSPENSION

The Upper Set of Curves Illustrates the Difference in Period, Duration and Amplitude of the Same Steel Spring with (Dot and Dash Line) and without (Solid Line) Air-Springs when Passing over an Obstruction of the Same Height. The Combined Action of the Steel Spring and the Air-Spring at the Axle Is Shown in the Lower Portion. The Shaded Area Indicates the Work Done by the Air-Spring

spring effect, indicated by the shaded area, is the flexing or work done by the steel spring. Referring again to the upper portion of Fig. 5, the dot-and-dash line is the steel-spring action; it is the same as the inside boundary line of the shaded area and is moved up into the upper portion to show more clearly the decreased action, or bending, period and duration in the same steel spring when used in connection with the air-spring. In Fig. 5, it will be noted that the steel-spring vibration alone had a duration of 5½ sec. with a period of 87.2 vibrations per min., while the combination showed a duration of 3 sec. with a period of 60 vibrations per min. The steel spring, separated from the combination, showed a similar period; although it lags behind the combination curve slightly.

Fig. 6 shows the apparatus used. A standard Dodge front steel-spring was hooked up with a 2½-in. direct-acting air-spring so that either the steel spring alone or the combination of the steel spring and the air-spring could be compressed at the center or axle position through a lever arrangement, as shown. The spring-suspension was given a constant load by applying a permanent weight at the end of the lever and was then compressed by manpower so that 1½-in. additional compression movement was obtained at the center or axle. This additional force was applied quickly, and then the spring was allowed to vibrate freely at its own period. The recording instrument is a spring motor-driven paper-roll used in connection with an electrical timing-device, marking ½-sec. intervals on the moving paper. The average speed was approximately 15 ft. per min. This test is elementary and is not intended as a true example of actual working conditions; but it is exhibited to bring out the fundamental principle of air-spring suspension and to draw attention to the general characteristic involved in a typical air counter-spring arrangement. This same characteristic reduction in the period and the duration of the vibration is apparent in all the series of tests that have been made.

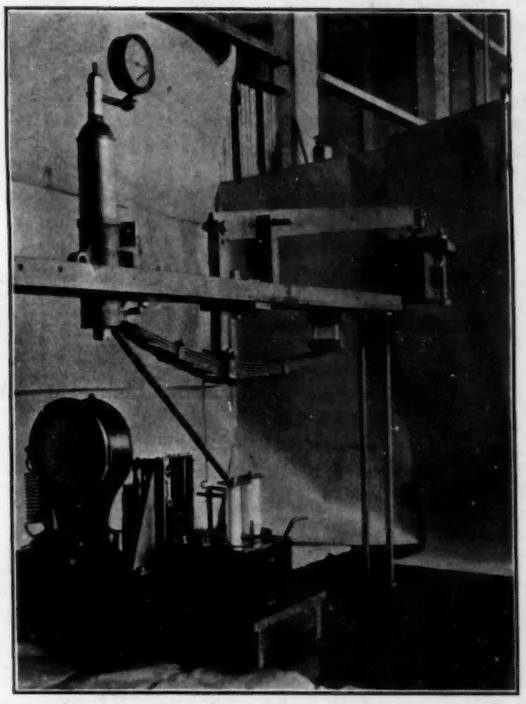


FIG. 6—APPARATUS USED IN MAKING THE LABORATORY TESTS OF EITHER THE STEEL SPRING OR THE COMBINED STEEL AND AIR-SPRING

The Moving Paper Roll Was Originally Designed for Use with the Seismograph That Can Be Seen in the Lower Left Corner. The Movements of Both the Steel and the Air-Spring Are Recorded Simultaneously on the Moving Paper, the Former by the Tubular Member Extending Diagonally Downward from the Air-Spring at the Upper Left to the Paper Rolls. The Combined Action at the Center of the Steel Spring Is Recorded by the Vertical Wire That Extends Downward from That Point to the Record Rolls

FRICTION CHARACTERISTICS

Regarding the friction that is present in the air-spring, I would say that it has a tendency to bind and stick. This is usually due to incorrect alignment, but there is also considerable trouble due to the design and the materials used in the air-spring itself. The friction present in the air-spring can be divided into friction due to cup-leather material and design, bearing or mechani-

cal friction of the moving element and that due to the lubricant used. It is not my intention to go into this particular phase of air-spring design, but simply to call attention to the improvements that are possible by research and refinement of design.

Fig. 7 shows the difference in static friction in different types of cup leather. Starting at the top, it is

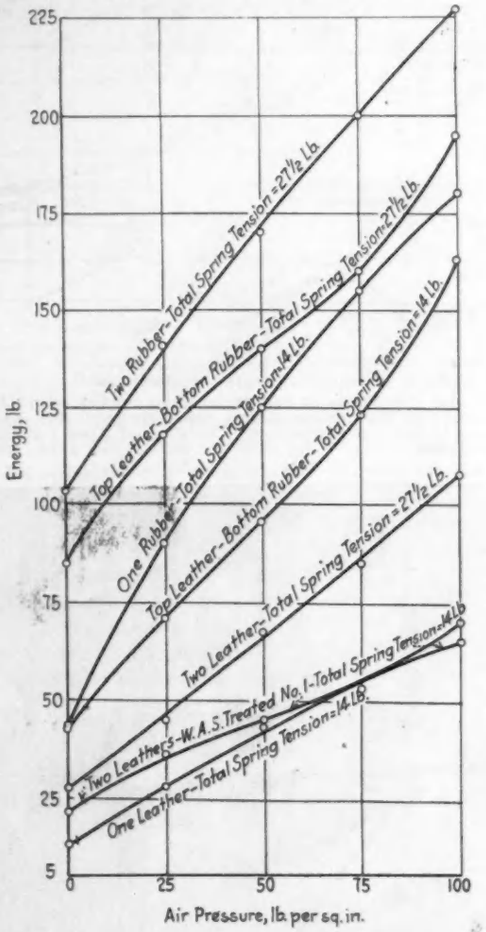

Energy, lb
Air Pressure, lb. per sq. in.
Two Rubber-Total Spring Tension=27½ Lb.
Top Leather-Bottom Rubber-Total Spring Tension=27½ Lb.
One Rubber-Total Spring Tension=14 Lb.
Top Leather-Bottom Rubber-Total Spring Tension=14 Lb.
Two Leather-Total Spring Tension=27½ Lb.
Two Leather-S-W.A.S. Treated No. 1-Total Spring Tension=14 Lb.
One Leather-Total Spring Tension=14 Lb.

FIG. 7—CURVES SHOWING THE DIFFERENCE IN THE STATIC FRICTION WITH VARIOUS TYPES OF CUP PACKING

Included in This Is the Friction of the Cup Washers, the Mechanical Bearing-Friction and That of the Oil. The Marked Difference between the Two Rubber Packings at the Top Having a Total Spring-Tension of 27½ Lb. and the Two Leather Packings at the Bottom Having a Total Spring-Tension of 14 Lb. Should Be Noted as Indicating the Importance of the Friction Factor

noted that two rubber packings having a total expander-spring tension of 27½ lb. present a serious friction problem. Comparing this curve with two leathers having a total spring-tension of 14 lb. at the bottom of Fig. 7, one can appreciate readily that this friction factor is highly important. All these tests were made on the same air-spring under nearly identical conditions, the only difference being the material used in the cups and the strength of the expander spring.

The curves in Fig. 7 represent the total static friction, including that of the cup washers and the oil and the mechanical bearing-friction. The last two factors are small in quantity in the type of spring that these tests were made on, as is indicated clearly by the difference in friction between the different kinds of cup leather

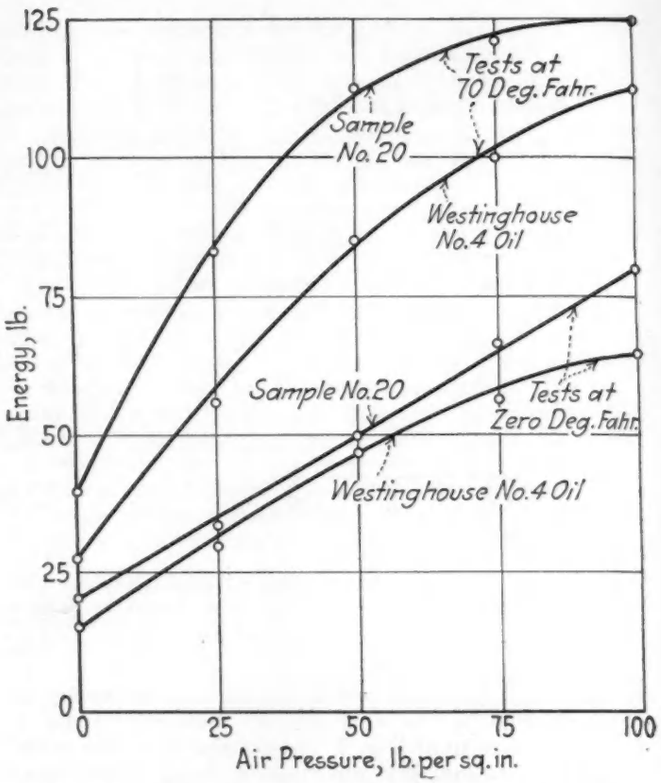

Energy, lb.
Air Pressure, lb. per sq. in.
Tests at 70 Deg. Fahr.
Sample No. 20
Westinghouse No. 4 Oil
Sample No. 20
Tests at Zero Deg. Fahr.
Westinghouse No. 4 Oil

FIG. 8—CURVES SHOWING STATIC FRICTION DEVELOPED WITH TWO DIFFERENT OILS

The Increase in Friction Due to Temperature Increase Is Very Noticeable with the Two Different Types of Oil Tested. This Is the Biggest Contrast Found in Over 300 Different Tests of Various Oils under Different Conditions. It Must Be Remembered That All the Static Friction, Including That of the Cup Leather, Is in the Curve. The Viscosity of the Two Oils Tested at Different Temperatures Is Given in the Following Table

Oil No.	4	20
Viscosity at 32 Deg. Fahr., Saybolt sec.	11,731	4,313
Viscosity at 65 Deg. Fahr., Saybolt sec.	2,230	791
Viscosity at 100 Deg. Fahr., Saybolt sec.	600	224

alone. Fig. 8 illustrates the difference in friction due to the oil factor. In all tests we have made in comparing different kinds of oil, we have found that a lower temperature will show considerably less friction.

Fig. 9 shows the increase in friction due to increase in temperature with our No. 4 oil. However, it seems that the viscosity of the oil has considerable to do with the friction and, if it were possible to obtain a zero cold-test oil that had a flat curve when its viscosity was plotted against temperature, and yet was of sufficient

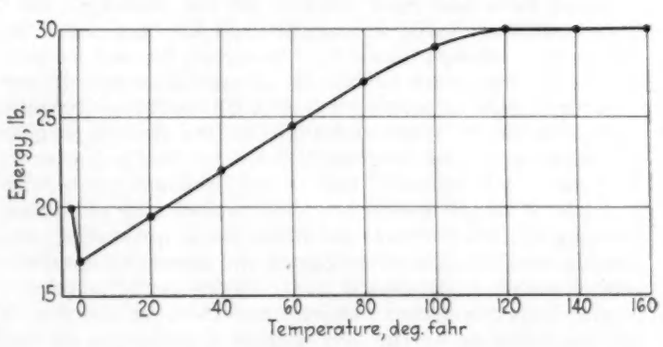


FIG. 9—CURVE SHOWING STATIC FRICTION INCREASE DUE TO TEMPERATURE RISE

All These Tests Are Made with 1-Hr. Rest Periods between Readings, So That the Cup Leather Will Set Tightly against the Cylinder-Wall, Thus Representing the Worst Case of Friction Found in the Air-Spring

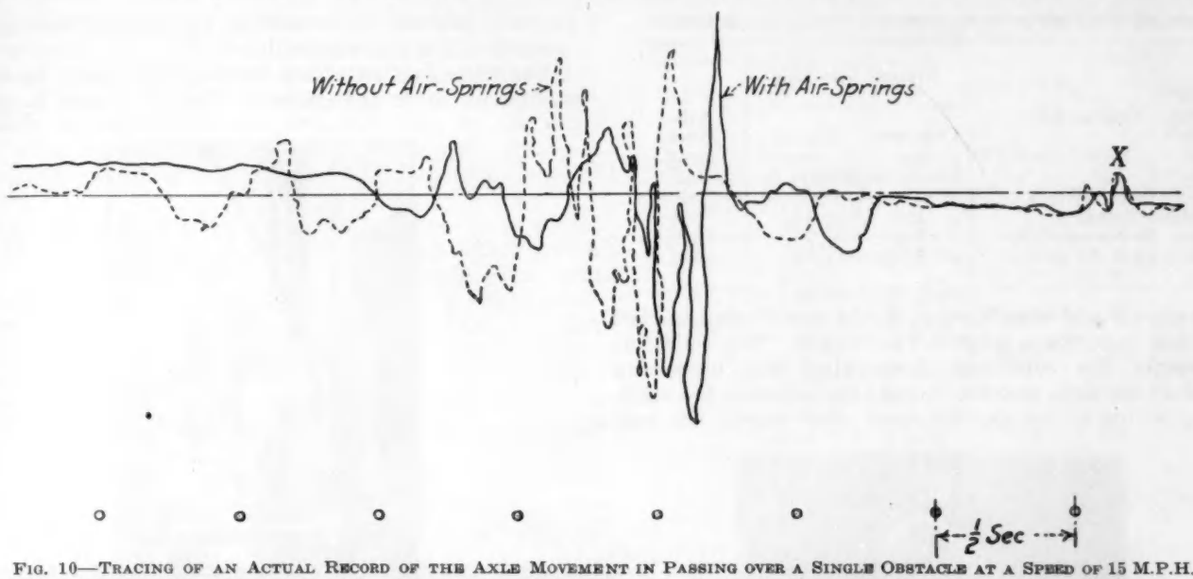


FIG. 10—TRACING OF AN ACTUAL RECORD OF THE AXLE MOVEMENT IN PASSING OVER A SINGLE OBSTACLE AT A SPEED OF 15 M.P.H.
The Solid Line Is the Movement of the Axle Relative to the Chassis with Air-Springs. The Dotted Line Is the Same Movement without Air-Springs. The Small Irregularity Marked X on the Right Side Is a Wide Crack or Joint in the Concrete, the Curves Being Superimposed and Lined-Up from This Point To Show the Relative Difference in Axle Movement

density to maintain a flexible film of lubricant around the moving element, one of the minor difficulties experienced in air-spring operation would be overcome. The subject of air-spring friction should be treated seriously.

FRONT-AXLE MOVEMENTS WITH AND WITHOUT AIR-SPRINGS

In the field tests a record of the movement was obtained by mounting a motor-driven recording paper-roll on the chassis, the recording pen being connected directly to the axle. A series of tests was made at various speeds over two different sizes of obstacles. The results always showed the same characteristic difference with and without air-springs. The single-bump curves mentioned for Fig. 10 were all taken at a car speed of 15 m.p.h. and show the axle movement as the car passes over a 2¾-in. high by 5½-in. wide plank laid on a cement road. Fig. 10 shows the curves obtained in these tests. The curves were superimposed to show the comparison

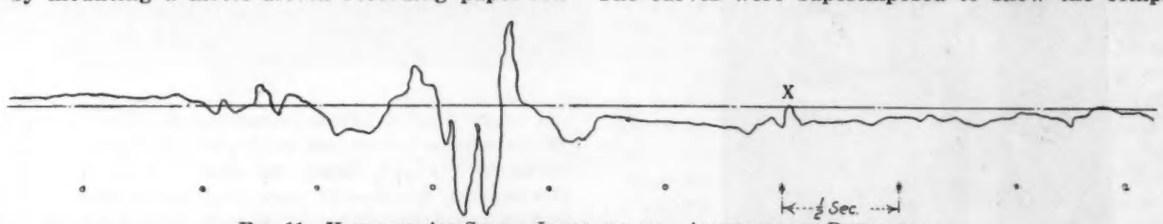


FIG. 11—HOW THE AIR-SPRING INCREASES THE AMPLITUDE OF DEFLECTION
The Record Was Obtained with the Same Car Passing over the Same Obstruction as in Fig. 10. In This Case the Car Was Completely Equipped with Air-Springs. As the Paper on Which the Record Was Traced Was Traveling at a Faster Speed, the Record Is Spread Out More than in Fig. 10

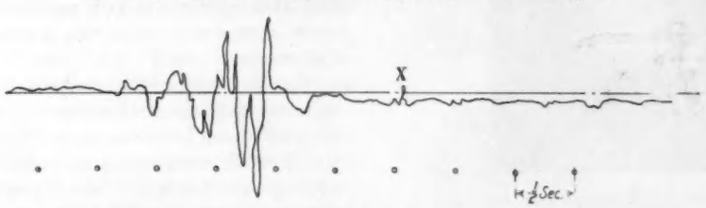


FIG. 12—RECORD OF FRONT-AXLE MOVEMENT IN PASSING OVER THE SAME OBSTRUCTION
In This Particular Test the Car Was Equipped with Air-Springs on the Rear Axle Only

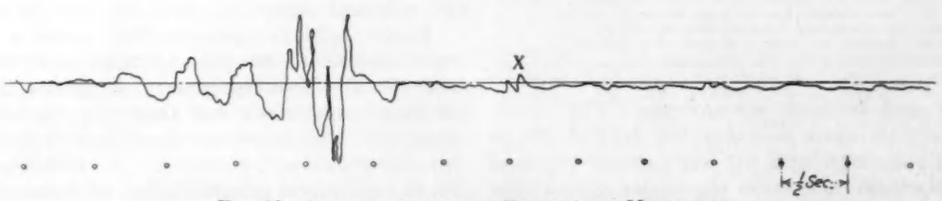


FIG. 13—ANOTHER RECORD OF FRONT-AXLE MOVEMENT
In This Case the Car Had No Air-Springs, Merely Being Equipped with the Original Steel Springs. The Curves Reproduced in Figs. 10, 11, 12 and 13 Were All Obtained at the Same Car-Speed, 15 M.P.H., and Care Was Taken To Have All the Other Conditions as Nearly Identical as Possible

TABLE 1—VALUES OF INITIAL, OR MAXIMUM, AXLE-MOVEMENT

Equipment	Normal Axle-Line		Total Axle-Movement, In.
	Compression Above, In.	Expansion Below, In.	
No Air-Springs	1 7/16	1 3/4	3 3/16
Rear Air-Springs Only	1 9/16	2 1/4	3 13/16
Air-Springs All Around	1 13/16	2 3/8	4 3/16

more clearly and were lined-up at the small bump marked *X* which indicates a joint in the cement. The solid line represents the combined steel-spring and air-spring action at the axle, and the dotted line indicates the steel-spring action at the axle only; in other words, the axle

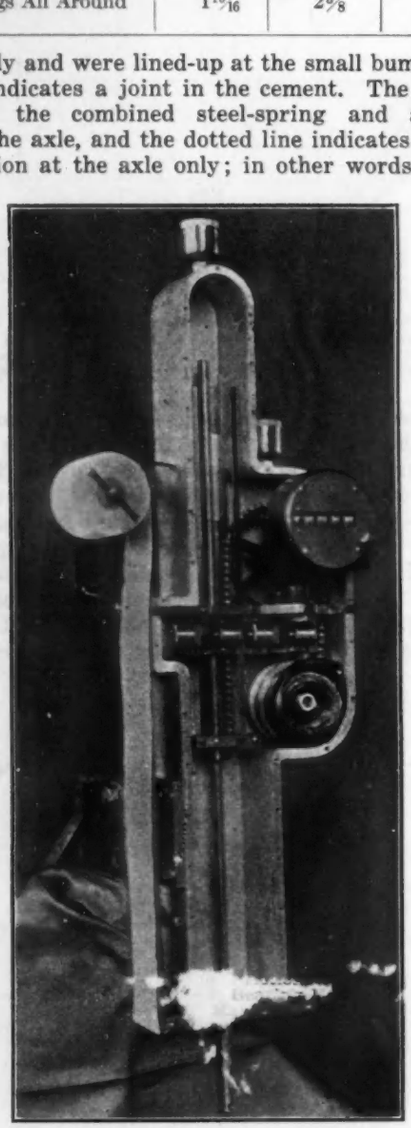


FIG. 14—MECHANICAL AXLE-MOVEMENT RECORDER WITH THE OUTSIDE COVER-PLATE REMOVED

This Instrument Measures the Total Travel of the Axle in Feet, the Number of Axle Movements, the Number of Times the Axle Passes the Normal Rest Line, the Actual Travel in Feet above the Normal Rest Line and the Corresponding Travel Below. Five Different Phases of Axle Movement Are Automatically Recorded by This Instrument

movements with and without air-springs. The maximum movement either above or below the normal line is increased with air-springs and the subsequent rebound shows considerably more action on the under side of the normal line, the general air-spring tendency being to float the chassis on a slightly higher plane at the time of rebound. In all our tests, a reduction is noticeable in the vibration period and in its duration with an increased axle-travel vertically.

The increased amplitude with air-springs is shown at its maximum on the curve in Fig. 11, which is spread

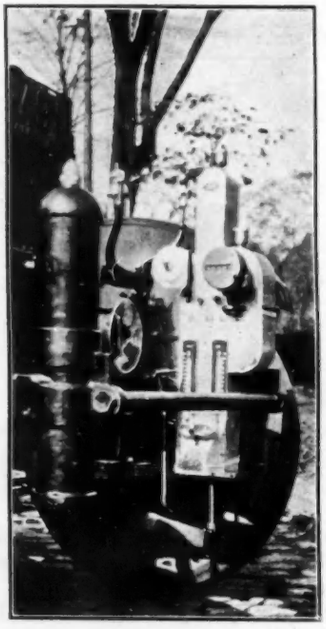


FIG. 15—THE MECHANICAL AXLE-MOVEMENT RECORDER AS IT IS ATTACHED TO THE FRONT END OF A CAR PREPARATORY TO MAKING A TEST RUN

The Connection between the Axle and the Instrument Is Made by an Angle-Iron Extension Projecting from the Front Axle and Connected to the Moving Rod of the Recorder by a Universal-Joint. This Arrangement Is Not Absolutely Accurate, but the Error Introduced by It Is Practically Negligible

out more due to faster paper-speed. The curve in Fig. 12 shows the same test with rear air-springs only. The curve in Fig. 13 shows the condition with the original steel-spring equipment only. All the curves were taken at the same car-speed, and care was used to make all other conditions as nearly identical as possible. These curves were selected from those for about 50 tests to get the maximum comparison in amplitude, as the total axle movement was the principal factor we desired to determine.

Table 1 shows the values of the initial, or maximum, axle-movement in inches. The figures in Table 1 were chosen from curves showing the minimum axle-movement with steel springs only, and maximum with air-springs all around. We have, therefore, a maximum increase in amplitude of 30 per cent at the axle, due to the influence of the air-spring. In actual figures this amounts to 3/8 in. more travel upward on the compression or shock stroke, and 5/8 in. more on the downward or rebound stroke.

Paper rolls for records that cover a long course are cumbersome to handle and tedious to work with. The records all show the general tendency illustrated in the single-bump curves, but they are far too complicated to analyze. Therefore, we developed an instrument we call an axle-movement recorder. It is shown in Fig. 14 and is an ingenious consolidation of recording dials, so as to act on one rod in the center, this rod being connected to the axle through a bracket and a universal-joint. Thus, all the movements of the axle are transmitted to

the instrument, which is designed so that it will record the number of movements irrespective of their amplitude and position in regard to the normal setting of the car. It records also the number of times the axle passes upward above the mean position and, likewise, the number of movements below; further, it gives the total accumulated travel of the axle vertically, up and down, in inches.

The instrument is secured to the chassis as is shown in Fig. 15. An angle-iron extension comes out from the axle to extend directly underneath the moving rod, and is connected to it by the universal-joint. A slight error is present in this hook-up, but we feel that it is not large enough to be considered. Fig. 16 shows another view of the instrument on the car, and Fig. 17 shows diagrammatically the movements of the axle in relation to the chassis, as well as the readings that are possible with this instrument.

All tests are made on a picked course. The factory course is an average rough country-road exactly 1 mile in length. The course forms a square; so, the start of

FIG. 16—ANOTHER VIEW SHOWING THE AXLE-MOVEMENT RECORDER ATTACHED TO THE CAR

This Instrument Is Provided with a Universal Bracket That Will Fit All Standard Cars With or Without Air-Spring Equipment. The Front Pan or Apron Must Be Removed During the Test

the run is also the finish. One-half the distance is level; one-quarter is down-hill and the remaining quarter is up-hill. The last quarter is sandy road "loose" enough to cause the average car to labor in high gear at a speed of 15 m.p.h. Table 2 shows a comparison of axle movements with and without air-springs. The same general increase in amplitude and average axle movements as is shown on the bump curves are again recorded.

Table 3 shows the results of a test conducted on the Yale University, Mason-Laboratory course, 5 miles in length. One-half the course was traversed at a car speed of 20 m.p.h., due to the fact that this is the best speed the average car can make over this section; the remainder of the run was at a speed of 25 m.p.h. Table 3 gives the relative reduction in axle movement at higher speeds with air-springs as compared with steel springs alone.

We have made tests recently on four-wheel-brake cars. The tests were all made on a Belgian-block course 1 mile long, the speed was 15 m.p.h., the same driver and the same load were used on all runs and each run was duplicated to avoid error.

Table 4 is a condensed report of the test. The sharp, snubbing action of the snubbing device is brought out clearly by the reduced axle-movements. On this type of road their effectiveness is almost negative; a snubbing

TABLE 2—STUDY OF AVERAGE AXLE-MOVEMENTS WITH AND WITHOUT AIR-SPRINGS[2]

Counter	Description	Without Air-Springs	With Air-Springs	Percentage of Reduction or Increase With Springs
A	Total Movement Up and Down, ft.	69.54	88.96	+28
B	Total Movement Above Normal Line, ft.	20.14	14.49	−29
C	Total Number of Movements	1,193	1,004	−16
D	Total Movement Below Normal Line, ft.	14.63	29.99	+105
E	Number of Times Axle Passes Normal Line	679	534	−21
2*B*/*E*	Average Movement of Axle Above Normal Line, in.	0.690	0.650	....
2*D*/*E*	Average Movement of Axle Below Normal Line, in.	0.435	1.350	....
	Average Axle Movement, in.	1.125	2.000	....
	Number of Vibrations Exceeding an Acceleration of 10 Ft. per Sec. per Sec.	354	286	−19
	Riding-Constant = Number of Vibrations Times the Weight Throw of the Instrument	72.9	49.3	−32½

[2] This test of a stripped Lincoln chassis was made over the factory course. The instruments used were the axle-movement recorder and the vibration machine.

device is at its worst on this type of road. We know that the same device on an average country-road will show a riding-quality improvement of from 10 to 15 per cent. The same decrease in free vibrations as was noted in previous tests is again apparent when we consider *C* showing 1674 vibrations without air-springs and 1386 with them; also the corresponding increase in *A*, the total amplitude, from 144.37 to 176.34 ft. These comparisons of *A* and *C* are for the columns with steel springs alone and air-springs only. The increase in maximum axle-movement is from 2 11/16 in. with snubbers to 3½ in. with air-springs, distributed so that 7/16

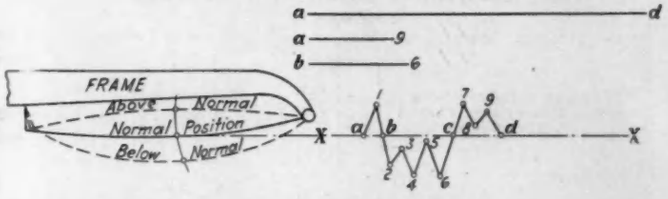


FIG. 17—GRAPHIC REPRESENTATION OF READINGS AS SHOWN ON VIBRATION RECORDER

Counter *A* Records the Total Vertical Movement in Feet in Either Direction, Up or Down. It Is Represented by the Line *AD* Which Is the Sum of *a*-1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9 and 9-*d*. Counter *B* Records the Total Movement in Feet in an Upward Direction above the Normal Line *XX*. It Is Represented by the Line A-9 Which Is the Sum of the Vertical Movements *a*-1, *c*-7 and 8-9. Counter *C* Records the Total Upward Axle-Movements Exceeding 3/32 In. Irrespective of Their Position in Relation to the Normal Line. The Points 1, 3, 5, 7 and 9 Are Recorded, But the Points 2, 4, 6 and 8 Are Not Recorded Since They Are at the End of the Down Strokes. Counter *D* Records the Total Movement in Feet in a Downward Direction below the Normal Line *XX*. It Is Represented by the Linear Length *B*-6, Which Is the Sum of *b*-2, 3-4 and 5-6. This Counter Is Just the Reverse of Counter *B*. Counter *E* Records the Number of Times the Axle Crosses the Normal Line *XX*. Thus the Points *a*, *b*, *c* and *d* Are Recorded when the Normal Center-Line Is Crossed in Either Direction by a Movement Exceeding ½ In. The Fact That This Instrument Measures Only the Relative Movement between the Frame and the Axle Should Be Borne in Mind

TABLE 3—RELATIVE REDUCTION OF AXLE-MOVEMENT

Date of Tests, Sept. 28, 1923	
Mason Laboratory Course, 5 Miles; Yale University Test Car, Lincoln Chassis, 1924 Design	
Mason Laboratory Instrument Used	
Car Weight, lb.	
Front	1,880
Rear	2,060+640
Total	4,580
Tire Size, in.	
Front	33x5
Rear	33x5
Inflation-Pressure, lb. per sq. in.	
Front	60
Rear	60
Wheelbase, in.	130
Speed, m.p.h.	20 to 25
Number of Passengers as Load	3
Duration of Test, min.	30

Readings	Steel Springs Only	With Westinghouse Air-Springs	
A	484.68	583.68	563.06
C	7,114.00	6,574.00	6,387.00
E	5,864.00	1,717.00	1,890.00
Riding-Constant, per cent	46	85	85

in. is the increase in compression and 3/8 in. the increase in rebound, a total increase of 13/16 in. in maximum axle-movement. This is the highest individual movement recorded; it is not the average maximum-movement, which of course is considerably less.

A rough Belgian-block road generally will show more vibrations and accumulated axle-travel, as both the steel springs and the air-springs must work continuously at faster average-intervals with longer average axle-travel. Generally speaking, the air-spring suspension is there at its best and the snubbers at their worst. As all our tests at present are made to secure data pertaining to the operation of a certain car *with* and *without* air-springs, we leave out certain factors that affect riding-quality, such as the center of gravity, balance and the ratio of sprung to unsprung weight. The influence of the air-spring at the axle is contrasted best at a speed of 15 m.p.h., as the degree of difference in action between the two cases seems to be at its maximum at this speed.

TABLE 4—STUDY OF ROAD TEST OF FRONT-AXLE MOVEMENTS[1]

Percentage of Improvement in Riding Quality over That of of Steel Springs Alone	Constant 91.0	Percentage of Loss 0.34	Constant 88.0	Percentage at Start=0	Constant 69.5	Percentage of Increase 21	Constant 45	Percentage of Increase 49
Front-Axle Movements	Snubbers No. 1		Steel Springs Alone		Air-Springs and Snubbers No. 1		Air-Springs Alone	
A—Total Up-and-Down Movement, ft.	77.34		144.37		99		176.34	
C—Total Number of Movements	765		1,674		823		1,386	
E—Number of Times the Axle Passes the Normal Line	967		1,724		891		332	
F—Maximum Axle-Travel Above the Normal Line, in.	1 7/16		....		1 3/4		1 7/8	
G—Maximum Axle-Travel Below the Normal Line, in.	1 1/4		....		1 1/2		1 5/8	

[1] This test was made at a speed of 15 m.p.h. on a rough cobblestone and Belgian block course 1 mile in length.

The compression curve of the air-spring alone is practically isothermal, and, as the steel spring shows a straight-line curve, the combination curve reaches a point where the spring scale of the combination equals that of the steel spring alone; yet, in the ordinary working zone, the combination-spring scale is considerably weaker than that of the steel spring, which explains the difference in axle-movement. Therefore, the air-spring increases the total axle-amplitude, the vertical, up-and-down flexibility, approximately 28 per cent and reduces the amplitude that is above the normal line approximately 29 per cent; but it increases the same total amplitude below the normal line 105 per cent, thus pushing the theoretical normal line or axis of the axle vibration away from the chassis under running conditions only. The duration of the axle vibration is reduced. Reference is made to Figs. 10, 11, 12 and 13 and also to Table 2. The net reduction over a period of time is approximately 16 per cent, or say a reduction in axle-movement from 5 vibrations per sec. without air-springs to 4.12 vibrations per sec. with them. This reduction is a natural function and still leaves the axle free and flexible in both directions; yet it is capable of very fast action in absorbing shock and making contact with the ground in depressions. The general effect is to smooth out the body line of travel and reduce the objectional vibrations in the chassis and the body.

Measuring Riding-Comfort

Before pointing out the weaknesses of instrument design, let us consider the other factors that are important in making a road test; and let us keep in mind the fact that, primarily, we want to measure the general riding-quality of the car. Then we can specialize and find out what a certain type of suspension will do on a certain type of road. The two constant factors in making any road test are (*a*) the course and (*b*) the instrument. A good course should have a variety of types of road surface, grades both up and down and some turns. It should be of sufficient length to average the human error that is bound to occur in driving. The variable factors are (*c*) the speed and (*d*) the ability of the driver to retrace his course in identically the same path at identically the same speed. The two variable factors, (*c*) and (*d*), are not so easy to control, especially on a rough course that winds and turns; but this is the type of course on which to compare the general riding-quality of any car.

Test runs on particular types of road on straight courses are also of value in determining the performance of any certain car on that particular type of road; generally, they give an indication of what one would expect the car to do on an entirely different type of road, but often they are misleading. A good example of this is that certain snubbing devices are really of negative value on a certain type of road at a given speed, but on an entirely different character of road they will improve the riding-quality of the vehicle considerably. Everyone who has worked long enough on spring-suspension has at some time given some thought to the instrument to be used in measuring riding-comfort, and everyone appreciates that a certain amount of error is unavoidable. The problem is to keep the percentage of error low. The simplest and easiest way to accomplish this is to use an instrument that is an automatic unit-recording machine, making all tests a matter of relative value; the instrument error will vary slightly under different

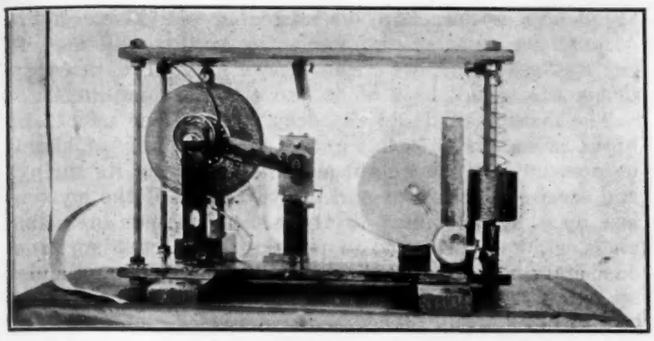


FIG. 18—THE VERTICAL VIBRATION-RECORDER THAT OPERATES ON THE SAME PRINCIPLE AS A PEDOMETER

In Its Present State of Development the Device Is Considered Reliable Enough To Give Fair Average Comparisons as to the Relative Merits of Different Spring-Suspensions. The Recording Apparatus of a Pedometer Is Impelled by an Oscillating Weight Supported by a Lever Arm, the Entire Mass Being Nearly Counterbalanced by an Adjustable Spiral Spring

conditions, but the comparison includes the error in any number of cases and, if the other factors in making the test, such as the course, the speed and the driving have average values, the comparative result will be an average.

AXLE-MOVEMENT RECORDER

We have experimented with a number of different devices and, after considerable preliminary work, have decided that the spring-suspended weight-type is best suited for our work. We sidetracked the seismograph principle for the same reasons that we gave up trying to analyze long graphical axle-movements, and developed a mechanical axle-movement recorder. We appreciated the accuracy of the records as traced graphically in both cases, but the work of analyzing hundreds of different test runs could not be considered. The spring-suspended weight-type undoubtedly is open to criticism because it requires inherent damping action to remove the effects of its own vibration; moreover, some of the instrument vibration will be accumulated with the car vibrations and cannot be separated from them. However, this type can be depended upon to tell the riding story accurately enough to be of immense value in comparing the results obtained with various spring-suspensions.

The design may have a vertically operated weight or one that swings on the arc of a circle. The latter type, though complicated and limited in action, is attractive, as a low-period flat spiral-spring can be used easily to support the weight, and the accumulated vibrations can be recorded easily. The sensitiveness can be controlled by the amount of the weight that is supported by the spring. Just how sensitive the instrument should be is unimportant right now, but at some future time this question must be answered because we must decide what acceleration is objectionable for both the passengers and the car. The period and the amplitude of any given vibration govern the acceleration and, likewise, the sensitiveness of the instrument.

The instrument we are using now is yet in a crude state, yet we consider it reliable enough to give fair average comparisons as to the relative merits of different spring-suspensions. Fig. 18 is a photograph of an early instrument. It is nothing more than an "over-grown" pedometer. The recording apparatus of a pedometer is impelled by an oscillating weight that is supported by a lever-arm, the whole mass being nearly counterbalanced by an adjustable spiral spring. The pedometer records the vertical movements of the human body, and then attempts to translate these movements into terms of distance covered. The translation is the difficult part but, for the purpose for which we use our device, the record needs no translation into terms of distance covered and so the problem is much simpler.

Fig. 19 shows the instrument we are now using. It is compact, easily handled and can be used by any skilled mechanic. It is simply a refinement in both design and workmanship of the crude device shown in Fig. 18. The weight is spring-suspended through the radius-arm, the spring being located in a central position on the outside of the friction drum that actuates the tape. This drum is floated on ball bearings and rotated by pawls that connect to the radius-arm, so that it gives motion only in one direction.

METHOD OF RECORDING VIBRATIONS

Regular ticker-tape is used to record the vibrations. This tape is pulled by the rotation of the friction drum as the weight goes up; so, when the weight returns, the tape is stationary and a small pin in the weight perforates and leaves a permanent record on the tape for each throw. A long throw will show considerable space between the perforations. Short, snappy, fast vibrations condense the perforations. The entire story, therefore, is written on the tape. Measuring the length from the first perforation to the last, we have the accumulated weight travel. By counting the perforations, we have

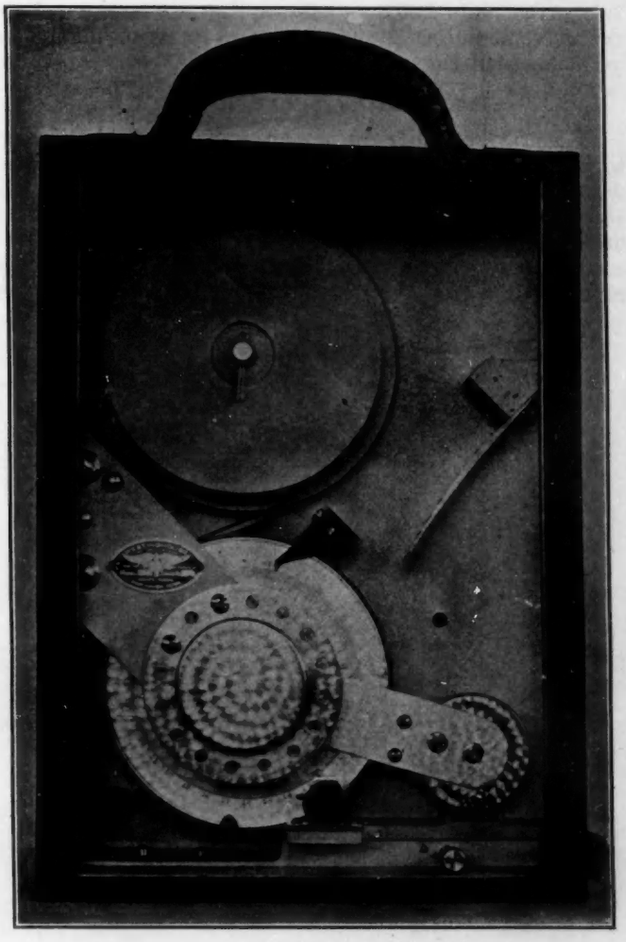


FIG. 19—THE PRESENT VIBRATION INSTRUMENT

This Is a Development of the Instrument Shown in Fig. 18 and Involves the Same Principles. This Instrument Weighs 15½ Lb., Is Totally Enclosed on Three Sides with Non-Breakable Glass Windows, So That Its Action Is at All Times Visible to the Tester. It Simply Records and Writes Down the Impression of the Passenger as the Shocks Occur

the number of vibrations in excess of a certain acceleration that the instrument is set for. As the tape may slip because it is friction-fed, a positive mechanical counter is used to check-up the tape length. This counting attachment records the radial movement of the friction drum in degrees and is used in connection with an individual counter that registers each complete rotation of the drum. This counting attachment gives a quick answer and an accurate indication of the results that are to be expected on the tape. The instrument is set to record each and every vibration exceeding an acceleration greater than 10 ft. per sec. per sec., and its approximate limit is an acceleration of 40 ft. per sec. per sec. The larger vibrations are thus recorded as they occur, because the throw of the weight is governed by the force of the shock. The record on the tape, therefore, shows the total number of vibrations exceeding an acceleration of 10 ft. per sec. per sec. and also the accumulated intensity of all the vibrations that exceed the acceleration just stated.

We have found it necessary to consider both of these factors, as it is possible to reduce the accumulated accelerations at the expense of increasing the total number of vibrations. In other words, the intensity of a certain vibration will be partly damped out but will result in additional forced vibrations in the car itself. The introduction of any damping device, positively connected between the main body and the spring, will always limit the movement, but it will likewise increase the forced oscillations in the structure as a whole.

Acceleration and Frequency

Acceleration and frequency are unquestionably the factors we have to measure to classify riding-quality. Just what combination of acceleration and frequency is objectionable and destructive is a question that has been asked many times and as yet not answered. We have assumed an acceleration of 10 ft. per sec. per sec. to be objectionable and have also considered that the more frequently an acceleration exceeding the above figure occurs, the more objectionable the results will be. In saying "assumed," we mean it; we have no data or experiments to fall back on to prove the assumption.

The instrument is 3⅜ in. deep, 8¾ in. long and 12 in. high; it weighs 15½ lb.; and is made entirely of aluminum except for the weight element, including its springs and screws. The front and the two sides of the housing are open at all times to inspection, as non-breakable glass windows are used to protect the mechanism from dust and dirt. The front window is removable and slides up out of the way when adjustments or a new roll of tape are required. The sensitiveness of the weight is governed by rotating the spiral-spring cap, which is locked in place by two set-screws. An ordinary phonograph-needle is used in the weight element as the perforating pin and is easily replaceable.

The instrument can be considered dead-beat for practical purposes, as we have succeeded after considerable trouble and experimentation in eliminating any rebound or recording action of the weight on its return stroke when it perforates the paper, irrespectively of the throw of the weight, which, of course, is governed by the intensity of the acceleration registered. To do this we had to use a low-period flat spiral-spring in connection with the radius-arm, which is really a lever that multiplies the static deflection of this spiral spring. The friction drum is a hollow aluminum casting, made particularly light to eliminate the trouble we had experienced from the inertia of this part. The stop for the weight itself is located off the center of gravity at a slight angle, to neutralize the natural rebound action.

Friction

Friction is eliminated as much as possible in both the upward and the downward movements of the weight. The only resistance to the upward motion is that of the pawl, which engages the friction drum, rotates it and moves the tape. On the down motion the pawl is in-

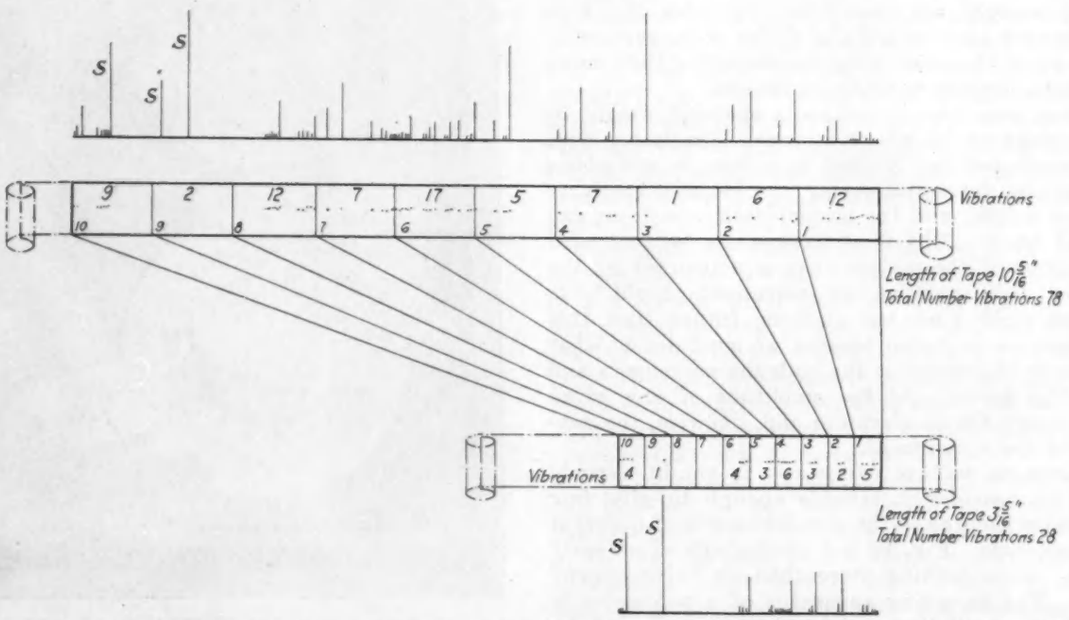
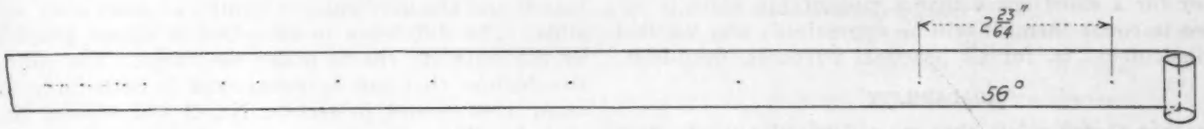


FIG. 20—GRAPHIC CHART SHOWING THE COMPARISON OF ACTUAL TAPE-RECORDS AS MADE ON THE VIBRATION RECORDER

The Upper Record Was Made Without Air-Springs and the Lower One With. The Difference in Vibration Is Shown Graphically by the Intensity Charts under Each Tape. The Only Similar Feature That May Be Recognized in Both Tapes Is the Bump That Occurs in Sections 9 and 10 on Both. These Vibrations Are Marked S on the Intensity Charts for Identification Purposes. They Were Caused by an Extra Large Chuck-Hole That No One Would Drive Through under Ordinary Conditions



Period	Amplitude, In.	Acceleration, Ft. per Sec. per Sec.	Drum Rotation, Deg.	Tape Movement, In.	Tape Movements
90	1 23/64	10.00	1	0.042	
90	2 1/64	15.00	6	0.250	
90	2 45/64	20.00	25	1 3/64	
90	3 3/8	25.00	44	1 27/32	
90	4 3/8	32.39	56	2 23/64	

0 1/4 1/2 3/4 1 1 1/4 1 1/2 1 3/4 2 2 1/4
Inches

FIG. 21—TRACING OF TEST TAPE SHOWING HOW THE INSTRUMENT RECORDED THE DECREASING AMPLITUDE AND ACCELERATION WHEN SET VIBRATING ON COIL SPRINGS

The Initial Deflection or Amplitude Was 4⅜ In. and the Period of Vibration Equaled 90. The Tape Movement for Certain Accelerations Is Indicated by the Spacing between the Dots and Is Given in the Table

operative. The flat cantilever spring just above the weight is placed there only to take care of violent throws that occur occasionally on very hard-riding light-trucks in bad country. The ordinary passenger-car rarely throws the weight against this stop. Even on an acceleration that will deflect the cantilever spring that has been mentioned ½ in. or more we have been unable to detect a rebound that will register or move the tape. When one considers that the tape record of some cars will at times show perforations that are so close to-

TABLE 5—COMPARATIVE READINGS ON TEST RUNS MADE OVER THE 1-MILE FACTORY COURSE[1]

Test No.	Make of Car	Type	Model of	Snubber or Shock-Absorber	Tape Record			Perforations		
					Length, In.	Average Length, In.	Per Cent	Number of	Average Number	Per Cent
22	Overland	Touring	1920	None	106 3/16	....	.....	510	...	....
23					107 9/16	106 7/8	.....	479	495	....
29	Lincoln	Sedan	1924	Device No. 6	37 29/32	....	.....	201	...	....
30					38 7/16	....	.....	226	...	....
31					32 7/8	....	.....	184	...	....
32					36 1/8	....	.....	199	...	....
33					34 27/32	36 1/32	.....	205	203	....
34	Maxwell	Sedan	1924	None	79 7/16	....	.....	321	...	....
35					79 3/8	....	.....	326	...	....
36					78 1/2	79 7/64	.....	324	324	....
46	Ford	Touring	1920	New Rear Steel Springs	91 7/8	....	.....	402	...	....
47					91 11/16	91 25/32	.....	379	391	....
48				Snubber No.3	79 5/8	....	.....	362	...	....
49					76 3/8	....	.....	362	...	....
50					77 1/16	77 11/16	.....	350	358	....
55	Pierce-Arrow	Sedan	1923	None	45 7/8	....	.....	294	...	....
56					47	46 7/16	.....	280	287	....
57				Snubber No.7	46	....	.....	300	...	....
58					41 7/8	43 15/16	— 5	264	282	— 2
59				Device No. 6	29 1/2	....	.....	220	...	....
60					27	....	.....	175	...	....
61					28 7/8	28 29/64	—38	195	197	—31
62	Essex	Coach	1924	None	98	....	.....	320	...	....
63					101 3/4	99 7/8	.....	300	310	....
64				Device No. 4	62 3/4	....	.....	237	...	....
65					61	61 7/8	—38	229	233	—25
89	Paige	Coupe-Sedan	1922	None	69 5/16	....	.....	353	...	....
90					67 1/2	68 13/32	.....	359	356	....
91				Snubber No.2	59 7/8	....	.....	388	...	....
92					62 3/4	61 5/16	—10	398	393	+10
93				Device No. 5	41 3/4	....	.....	311	...	....
94					46	43 7/8	—36	330	321	—10

[1] All of these tests were made at a speed of 15 m.p.h. with a load of two passengers.

gether for a short space that a magnifying glass is required to count them, it will be appreciated why we feel the instrument is, for all practical purposes, dead-beat.

"Roadability"

Another factor exists that we call "roadability"; it is closely related to riding-comfort. The instrument is of no help in measuring this factor, as it is purely one that is felt in the control or stability of the car. As this is a difficult subject to discuss, we will dismiss it with the comment that the present low-center-of-gravity car with its refinement in balance has automatically improved this factor. The improvement in this direction removes the main objection that has existed in the past to a more flexible spring-suspension.

Test Procedure

Our procedure in testing is to place the instrument on the floor of the car and to have the test operator hold it between his knees to prevent it from sliding or moving sideways. It can be placed anywhere in the car. We test principally to check-up the results obtained with air-springs. If the improvement is under the average figure expected for a particular make of car, further inspection is made to find the trouble and remove the cause before the car is released. Naturally, various makes and models of car in the same weight-class ride differently, and the improvement on some is not so great as on others, but the instrument reading generally will check closely on two different cars of the same make and model, provided they are both in the same condition.

Fig. 20 is a diagrammatic drawing showing a comparison of two tape records. The tapes were carefully traced and the perforations located as accurately as possible. The difference in vibration is shown graphically by the intensity charts under each tape. The only similar feature that can be recognized in both tapes is the bump that occurs in section No. 9 and section No. 10 on both; these vibrations are marked *S* on the intensity charts. This bumpy spot in the road is toward the end of the course, and is an unusually large chuck-hole that no one would drive through under ordinary conditions. The upper tape shows three large vibrations at this point while the lower one shows only two, although the intensity of the initial shock appears to be the same in both cases. Fig. 21 gives more clearly the story of the record on the tape.

Table 5 is presented to show the results obtained with the instrument in an endeavor to bring out the fact that the error is divided somewhere between the instrument and the driver. The largest variations in readings are shown in tests Nos. 29 to 33. As I remember, the air-spring equipment had just been put on and the springs were somewhat stiff. This might easily account for the difference in readings.

We find, generally, that two cars of the same make and type, tested under the same conditions, will ride in a very similar manner if they are both in good condition. All our tests are made by skilled men who try to produce the same conditions in testing cars. As our course is little used and well marked with wheel grooves, this is not a difficult matter. We find that any average driver will turn in approximately the same readings if the given speed is maintained. Our practice is to test each car that comes into our local service-station with and without the various devices that come with it. All

TABLE 6—AVERAGE RESULTS OF ROAD TESTS ON THE 1-MILE FACTORY COURSE AT 15 M.P.H.

Test No.	Make of Car	Type	Model of	Auxiliary Device	*A* Factor		*B* Factor	
					Number of Vibrations	Per Cent	Accumulated Riding-Factor, In.	Per Cent
1	Overland	Touring	1920	None	495	....	106.87	....
2	Oakland	Roadster	1919	None	428	....	124.00	....
3				Air-Springs	384	—10	60.31	—51
4	Maxwell	Sedan	1924	None	360	....	84.06	....
5				Air-Springs	345	— 4	68.93	—18
6	Dodge	Ambulance	1923	None	464	....	123.31	....
7				Air-Springs	349	—25	84.71	—31
8	Essex	Coach	1924	None	310	....	99.87	....
9				Air-Springs	233	—25	61.87	—38
10	Lincoln	Chassis + 640 Lb.	1924	None	333	....	94.62	....
11				Air-Springs	199	—40	39.34	—58
12		Sedan	1924	Air-Springs	203	—39	36.03	—62
13	Pierce-Arrow	Sedan	1923	None	287	....	46.43	....
14				Hydraulic Snubbers	282	— 2	43.93	— 5
15				Air-Springs	197	—31	28.45	—38
16	Dorris	Sedan	1924	None	366	....	101.06	....
17				Hydraulic Snubbers on Rear Alone	390	+ 6	82.18	—19
18				Air-Springs	217	—41	45.96	—54
19	Studebaker	Coupe-Sedan	1924	None	363	....	96.65	....
20				Snubbers	356	— 2	83.50	—14
21				Air-Springs	165	—55	29.50	—69
22	Paige	Coupe-Sedan	1922	None	356	....	68.40	....
23				Snubbers	393	+10	61.31	—10
24				Air-Springs	321	—10	43.87	—36

TABLE 7—COMPARATIVE TESTS WITH FOUR-WHEEL-BRAKE EQUIPMENT[5]

Test No.	Make of Car	Type	Model of	Auxiliary Device	*A* Factor		*B* Factor	
					Number of Vibrations	Per Cent	Accumulated Riding-Factor, In.	Per Cent
1	Cadillac	Touring	1921	None	141	....	25.87	....
2				Air-Springs	121	—14	13.81	—47
3	Cadillac, Four-Wheel Brake	Coupe	1924	None	287	....	29.09	....
4				Air-Springs	157	—45	13.89	—52

[5] This test was run over the 1-mile factory course at a speed of 15 m.p.h. For this test, the instrument was adjusted to lift at a 70-vibration period with a 3½-in. movement.

tests are duplicated, and in some cases triplicated, so as to avoid error and get a fair average-reading.

Results of Tests

Table 6 covers the results obtained with a few different cars; it shows the difference in riding-quality. Often a particular car of a given model is either much better or worse than the average of that model. This is due, principally, to its general condition, as the engine vibration and the spring efficiency are reflected in our readings. A study of Table 6 brings out the interesting fact that all the devices we have tested so far do improve the riding-quality and that the improvement is generally proportionate to the condition of the car. A startling example of this is the Studebaker sedan, which shows a 14-per cent improvement in riding-quality with snubbers, and a 69-per cent improvement with air-springs. Both percentages are above the average improvement gained with either device on the average car.

The general average improvement shown by snubbers, either of spring or of hydraulic type, is 10 per cent; and that of the air-spring, 35 per cent. The results of our tests so far seem to indicate that a good spring-type snubber is equally as efficient as an hydraulic type. It is again apparent that a snubber of either design does not decrease the number of vibrations materially. Generally, it shows a 2-per cent decrease, and under certain conditions will increase the vibrations to such an extent that the improvement in riding-quality is lost. The air-spring, on the other hand, usually will show a 30-per cent decrease in the number of vibrations. Snubbers are like air-springs; some are better than others. It is not my intention to give an opinion on the performance of any certain snubber or air-spring. These comparisons are made only to show the general difference in performance between the two types of auxiliary suspension.

A comparison of the performance of a four-wheel-brake car is interesting. We made some tests recently on two cars of the same make. The rear-brake car was an open model, 2 years old; the four-wheel-brake car was a coupe, almost new. Table 7 shows the results. It indicates that an auxiliary device will show a greater improvement on a four-wheel-brake car than on the regular rear-wheel-brake type.

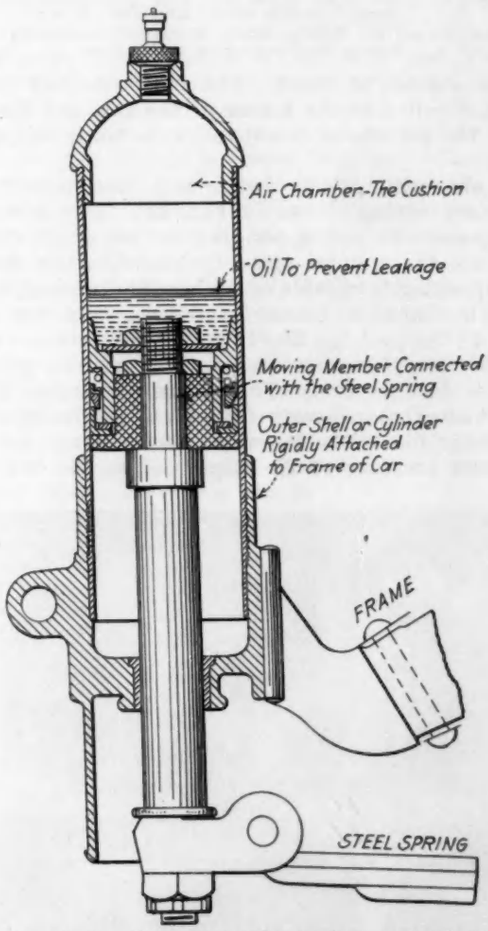

Air Chamber-The Cushion
Oil To Prevent Leakage
Moving Member Connected with the Steel Spring
Outer Shell or Cylinder Rigidly Attached to Frame of Car
FRAME
STEEL SPRING

FIG. 22—AN ELEMENTARY DIRECT-ACTING AIR-SPRING SHOWING ITS GENERAL CONSTRUCTION AND PRINCIPAL ELEMENTS

The Cup-Washer Packing around the Piston-Head Serves To Retain the Oil Above the Piston and the Oil, in Turn, Is the Medium for Retaining the Air under Pressure within the Cylinder. Air under Pressure Is Introduced into the Upper Chamber through an Air-Valve from an External Source. The Pressure in the Lower Chamber Is Normally Atmospheric, But a Sudden Movement of the Piston Serves To Build-Up Momentarily a Pressure That Acts as a Rebound Check. The Outer Shell of the Air-Spring Is Bolted to the Frame of the Car and the Lower End of the Piston-Rod Is Connected to the Existing Steel Spring

Air-Spring Design and Construction

The design of an air-spring is built up around the elements as shown in Fig. 22. This elementary spring is little more than a refinement of a veteran spring of 1841, and is adapted to installation on the modern automobile. The cup-washer packing around the piston-head serves to retain the oil above the piston; and the oil, in turn, is the medium for retaining the air under pressure within the cylinder. Air under pressure is introduced to the upper chamber through an air-valve from an external source. The pressure in the lower chamber is normally atmospheric, but a sudden movement of the piston serves to build-up momentarily a pressure that

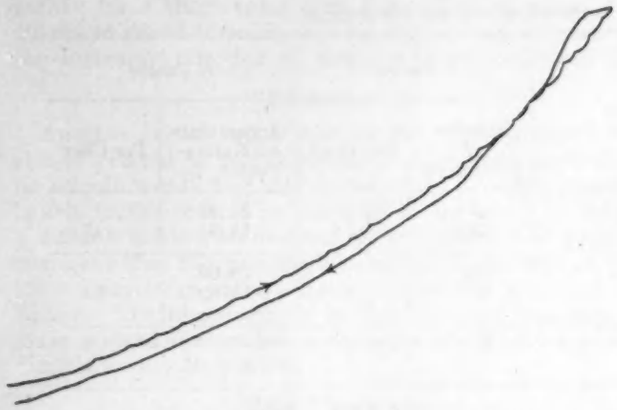


FIG. 23—INDICATOR-CARD MADE ON THE CONVENTIONAL CROSBY STEAM-ENGINE INDICATING DEVICE

This Card Shows the Characteristic Pressure Increase as the Air-Spring Is Compressed under Load

acts as a rebound check. The outer shell of the air-spring is bolted to the frame of the car, and the lower end of the piston-rod is connected to the existing steel spring.

The air-spring of late design is a development of the elementary spring shown in Fig. 22. This spring has two cup-washers, and is designed so that an air chamber opens into the annular space between the two washers. Either packing is capable of taking the full load, but the design is intended primarily to use only the upper washer as the packing that takes the continuous variable loads that are present in the pressure chamber when the spring is in operation. The pressure chamber is subject to loads that will vary from 25 to 150 lb. per sq. in. in ordinary use. The lower washer is generally under a constant pressure of 25 lb. per sq. in. If the upper washer is absolutely tight and no leakage occurs, except for the gradual seepage that is present in some degree in all cups, the pressure on the lower cup-washer will remain constant, but, if there is a slight leak, the extra oil will build-up in the air chamber that opens into the annular space between the two cups and compress the trapped air in it. The action is then similar to that of an ordinary air-chamber pump. The piston moving up and down gives the necessary drop in pressure in the carrying chamber, and, if sufficient oil has leaked by the upper cup to build-up a pressure that is greater than the decreasing pressure in the upper chamber on the pull-out stroke of the air-spring, the oil will be forced back by the edges of the upper cup-washer into the pressure chamber.

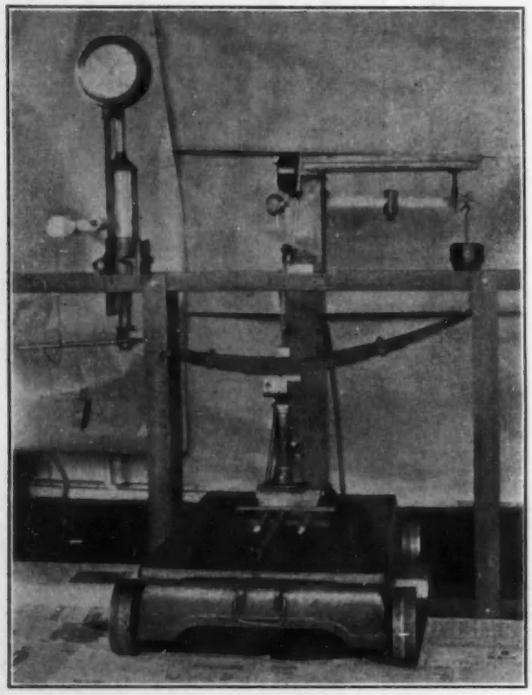


FIG. 24—APPARATUS USED IN OBTAINING THE INDICATOR-CARD REPRODUCED IN FIG. 23

The Crosby Device Is Located at the Left and Is Operated in the Conventional Steam-Engine Method. A Hydraulic Jack Was Used in Compressing Both the Air and the Steel Spring at the Same Time when Getting the Reading. This Accounts for the Wavy Line on the Up-Stroke as Shown on the Indicator-Card

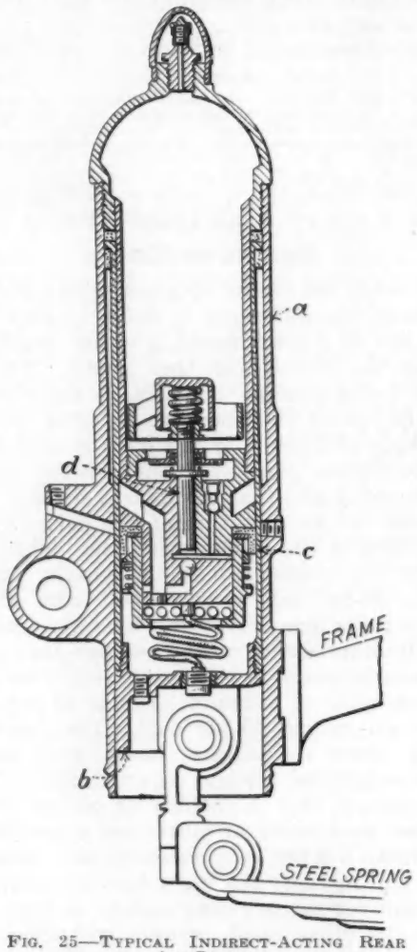


FIG. 25—TYPICAL INDIRECT-ACTING REAR AIR-SPRING

This Spring Is Substantially the Same as the Original Invention of George Westinghouse in 1912. The Guide or Rigid Outer Member *a* Is Permanently Bolted to the Frame. The Cylinder or Sliding Moving Member *b* Is Supported by the Column of Air under Pressure in the Dome, *c* Is the Cup-Leather Seal and *d* Is the Pump That Is Actuated by the Flow of Oil Passing Back and Forth from the Lower Chamber to the Upper and Is Designed as an Extra Precaution To Take Care of Any Oil Leakage That Gets By the Cup Packing *c*, Its Duty Being To Return It to the Upper Pressure-Chamber

In this construction a pumping action occurs only with leakage and the top cup-washer takes all the hard knocks, leaving the lower one as the last line of defense. Even with a poor upper cup-washer, the lower one is protected from the full force of the changing pressures above, and it is also apparent that the effective pressure

FIG. 26—ASSEMBLING A DIRECT-ACTING AIR-SPRING
The Workman Has the Cylinder in His Right Hand and Is Just Preparing To Slip It Over the Piston-Head That Holds the Two Cup Leathers. The Springs Are First Assembled as a Unit in the Cylinder and Then Assembled in the Guide or Outside Member That Is Bolted to the Bracket on the Frame of the Car

on the top cup-washer is cut down by the fact that pressure is present on the under side. An air-spring of this type is commonly known as a "direct-acting" spring; that is, it has a compression curve that is practically isothermal.

Fig. 23 shows an indicator-card taken with the air-spring connected to a steel spring and the load applied at the axle location. The trembling line is the up-stroke; the straight line is the return stroke as the load is released. Fig. 24 illustrates the apparatus used in getting this last curve. The indicator-card instrument is shown at the left in a horizontal position. An ordinary hydraulic jack on rollers was utilized to compress both the air-spring and the steel spring. The stepping-up action of the jack is reflected in the trembling compression-line.

Fig. 25 shows an earlier type of air-spring than the direct-acting type that has just been described. It has stood the test of time and is still being manufactured. The view shows the air-spring in collapsed position. Actually, for riding conditions, the spring will be pumped-up so that the cylinder or piston is in mid-position. The main elements of this spring are the cylinder *b*, to which the steel spring is connected, and the outer shell *a* and inner parts *d*, all as one element attached rigidly to the frame of the car. The interior is filled with sufficient oil to keep the cup-washer *c* covered at all times. The partition between the upper and the lower chamber contains the pump and pump body. Oil completely fills the lower chamber at all times and fills the upper chamber partly. A compression stroke of the cylinder drives the oil through the bypasses in the pump body into the upper chamber, compressing the air. On the return stroke, the oil is forced back by the air-pressure into the lower chamber. Any oil that leaks past the cup-washer is trapped in the annular reservoir above it, whence it is caught up by the pump and returned to the pressure chamber.

The pump consists of a closely fitting plunger in the pump body, directly connected to a flapper valve that is actuated by the flow of oil back and forth from one chamber to another. This pump, though entirely different in every way from that used in the direct-acting spring, is there for the same purpose, namely, to act as a secondary line of defense in the event that the cup-washer is not absolutely tight. The important points on air-spring design, therefore, are to

(1) Build it to maintain the pressure required to support the load
(2) Proportion the spring so that it has ample capacity for the load it is intended to carry
(3) Design the air-spring so that it is easily applicable to the average automobile

MANUFACTURE

Manufacturing an air-spring is a precision job. It is necessary to work to close limits and yet secure a certain freedom of movement for all moving parts under working conditions. A rigid inspection of material and

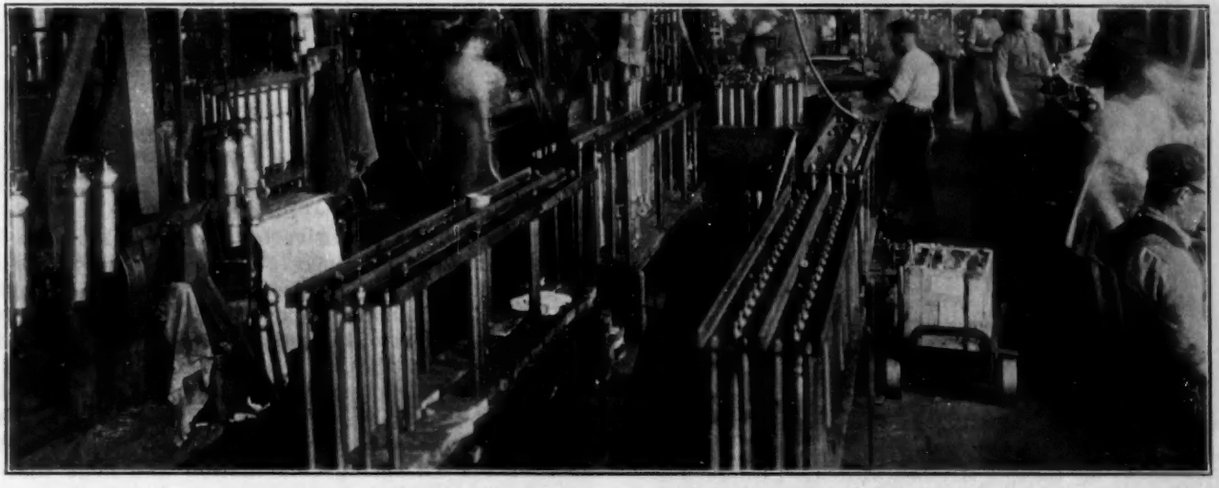


FIG. 27—VIEW SHOWING TESTING DEPARTMENT
The Air-Springs Are Set in Racks under Pressure and Closely Observed for Leakage, Either Oil or Air, During the Various Stages of Their Assembly

workmanship must be maintained throughout the course of manufacture. Each element that is to carry air pressure must be tested thoroughly to assure its being air-tight before it passes on to the assembling. Where a leather cup-washer is used, it is even necessary to treat each piece with a preparation that fills the pores in the hide. Next in importance is the finish given to the cylinders. These are ground to close limits both internally and externally. Any scratches, nicks or flaws in the material that might allow the escape of air or cause damage to the cup-washer cannot be allowed. In the machining operations, particular attention must be given to the alignment of surfaces, to facilitate assembling and secure flexibility of the spring.

The assembling department is responsible for building the spring up from the finished parts, testing the semi-finished and the finished product, and putting on the finishing touches such as painting. Fig. 26 shows a direct-acting spring being assembled. The piston-rod is held in the stand and the cup-washers, expanders and followers are assembled in order. The cylinder with the dome assembled is about to be slipped on over these parts. From this step the spring goes to the "dancers" to be worked-in. At the left of Fig. 27 are three springs of another type, but at the same stage of assembly, being run-in on the dancer. After being run-in, the springs are put into the frames, shown in the center of this view. Here they are put through an endurance test; that is, they are allowed to stand under pressure for hours and are inspected then for loss of pressure. The springs then encounter the final operation, where the guide or bottom is assembled. Fig. 28 shows the assembled spring again on the dancers. The purpose of this second run-in is to find any spring that would be a "sticker" under working conditions. Before the spring goes to the paint-room, it again goes through an over-night endurance test.

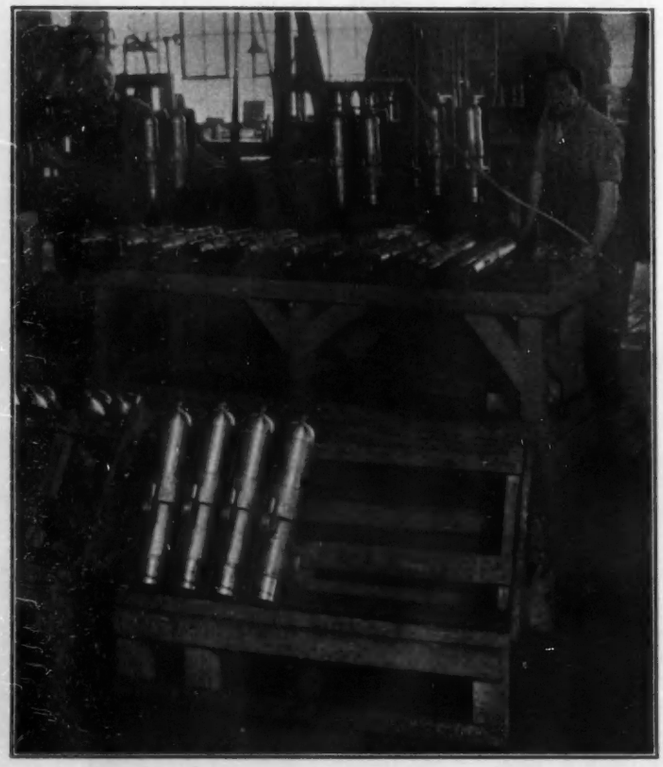


FIG. 28—FINAL TEST AND ASSEMBLY DEPARTMENT
This View Shows the Dancing Machines That Are Used To Work-Out the Air-Spring, Giving It the Same Up-and-Down Motion under Pressure That It Receives on the Road. This Second Run-In Is To Find Any Spring That Would Stick under Working Conditions

INSTALLATION AND SERVICE

The air-spring is, obviously, not a product to be sold by hit-or-miss methods. The one way to sell the air-spring properly is installed on the car. Only factory branches and qualified licensed representatives should make the installations. The labor involved is confined chiefly to fitting the brackets to the frame of the car. This must be done with care, so that the part of the bracket known as the pad, to which the air-spring is bolted, shall line-up perfectly with the frame and with the steel springs. Once the brackets are installed, the work of attaching the air-springs takes 1 hr.

Occasionally, an objection is made against cutting the frame of the car. It is not always necessary to do this when installing air-springs. Some frame makers, however, run the frames out so close to the spring-eyes that to attach the air-spring no alternative other than making a new cut-off is practicable. By so doing it is possible to build the bracket and the air-spring into the car so that the equipment presents the appearance of being really a part of the car and not an after-thought, as it would be if the original spring-hangers had been retained. Should a customer, in disposing of his car, wish to keep his air-springs for future use, we can always weld the pieces of frame back on the car, restoring it to its original condition. Owners have been known to resort to this step, even several times, before they could be prevailed upon to buy a new set of air-springs.

A built-in-bracket job that necessitates cutting the frame is always designed to keep the body in its original position; and, in some cases where the mudguards and body clearance will allow it, actually to lower the center of gravity. A good rule to follow is that the maximum increase in height over the axle must not be more than $\frac{3}{8}$ in.; and, if it is possible to design a "no-cut" bracket that will stay within this limit, by all means do it. But if the increase is more than $\frac{3}{8}$ in., by all means cut the frame and keep the body low. The importance of proper installation cannot be over-stressed, for it is so very closely allied with sales that, of the two, one can hardly exist without the other. A poor installation should never be made, for it not only increases sales resistance on the particular make of spring but also brings discredit upon any air-spring maker, whether he is responsible or not.

Where the installation ends, the responsibility for service begins. Despite the fact that the layman is qualified to give his air-springs whatever attention they may need, it is important that the manufacturer be in a position to render this service. Air-springs require a certain amount of attention to maintain the correct adjustment of riding position. About once monthly it may be necessary to add a certain amount of air. Oil-cup lubrication demands attention also to avoid the spring becoming inoperative because of lack of oil. The oil inside the spring, once it is adjusted to the proper amount, requires no attention other than to change it once or twice annually, depending on mileage and temperature variation. Shackle-bolts, bushings and the like must be renewed the same as other standard parts of the car. The life of the air-spring itself is dependent upon the usage to which it is put and the care it receives.

I again call attention to the riding characteristic load-curve of the air-spring combination and hope that its general characteristics will be studied and its natural advantages utilized to produce better riding-quality.

THE DISCUSSION

QUESTION:—What is the amount of air pressure in the air chamber?

J. J. MCELROY:—The air pressure varies with the weight of the car. Under normal load we generally try to carry between 60 and 75 lb. per sq. in. The pressure range, then, under actual operating conditions, is from 30 under expansion to 200 lb. per sq. in. under compression. We build 2½, 3 and 3½-in. diameter air-springs to take care of the cars of different weights.

QUESTION:—How long can the air-spring be run with the same air?

MR. MCELROY:—That depends on the mileage and the use. I have known cars to run 1 year or more. Generally speaking, any air-spring in fair condition ought to hold up 2 months without putting in additional air.

QUESTION:—Is any effort made to put the car springs into good condition while testing? Do you use oil?

MR. MCELROY:—If the steel springs come into our service-station in good condition, we do not touch them. If they come in rusted-up, we lubricate them with oil. In most of the tests we test the cars "as is," without attempting to lubricate the steel springs. However, by changing the tire pressure you can get better riding-quality.

QUESTION:—Do you install air-springs on the rear of cars that have cantilever rear-springs?

MR. MCELROY:—No. It costs too much to rebuild steel springs and that has to be done to put air-springs on the rear of such cars.

QUESTION:—What allowance is made for riding clearance, in consideration of the increased flexibility?

MR. MCELROY:—The average car has ample clearance on the front end but, in some cases where the front hanger has little drop, we increase the clearance about ¼ in. over the axle to take care of the initial shock-movement. After the first initial shock, the tendency with the air-spring is to rebound and work the axle farther away from the chassis. The single-bump curves shown illustrate how one single-bump back-reaction had a tendency following it to float the chassis slightly higher. Also, the increase from the initial shock on the up-stroke is considerably less than the increase on the down-stroke; so, the total increase of 25 per cent only amounts to an average of 10 per cent on the up-stroke. Sometimes, especially on custom-built jobs, we have trouble with the wheels hitting the fenders in the rear, the body being built too close for increased amplitude. Generally speaking, we try to keep the car at a normal level; but, if it is possible and we have plenty of mud-guard clearance, we lower it a little, say ¼ in., at the rear, in which case we add extra leaves to the steel spring.

QUESTION:—Is the tendency of air-spring equipment sufficiently definite to take advantage of designing the car 30 per cent lower to begin with and thereby prevent the abnormal raising while running?

MR. MCELROY:—Yes, if the car is so designed from the beginning; but I doubt if any material advantage would be gained, as the increased axle clearance obtained when the air-spring is working on a rough road is only about one-third of the additional axle movement, say 10 per cent in this particular case.

QUESTION:—How about an allowance for initial shock in such a case?

MR. MCELROY:—I did not take into consideration the additional percentage of initial shock, which would be ⅜ in., as I had in mind the knowledge that we do lower cars occasionally, sometimes as much as 5/16 in. all around, due to the fact that they originally had more clearance than was necessary. In the case of a new car-layout, I do not see how any saving could be obtained in axle clearance. Theoretically, it would have to be increased to take care of the initial shock-movement.

QUESTION:—Why, then, are extra leaves put into the steel springs when you make installations?

MR. MCELROY:—On the average car the front steel-spring had a 450-lb. spring-scale. The air-spring combination with it will reduce it to about a 250-lb. spring-scale, with the rising spring scale from there on. The rear spring has a spring scale of about 165 lb., and often it is necessary to put in extra leaves to get the proper combination; otherwise there would be too much flexibility and the movement on the rear end would be too great. We put less work on the steel spring, stop the flexing and throw the shock into the air-spring to get the proper combination. Usually, we figure that the best working condition is at least a 200-lb. scale rear-spring.

QUESTION:—Would the air-spring alone be a better job if it were free from friction?

MR. MCELROY:—I think not. Some friction or damping is apparently necessary, as an air-spring entirely free from friction would have a high period and I fear that it would transmit its vibrations to the steel spring unless some provision were made to cut down the duration of the vibration. On the other hand, too much friction is a serious matter, especially in view of the fact that the static friction of an air-spring after it remains for some time in a cold garage is at least 10 times greater than the sliding friction.

A MEMBER:—Complete tests and descriptions of an interesting pneumatic suspension for bicycles and automobiles are reported in a paper by Archibald Sharp, an English engineer, its title being Pneumatic Springs for Road Vehicles.[6] The piston cylinders have no contact with one another and are attached with what Mr. Sharp terms a "rolling packing mitten." One side of it is attached to one member, the other side to the other member, and the mitten rolls over on itself, as a golf stocking is rolled. Two advantages are said to result, approximate elimination of friction and permanent trapping of the air inside the mitten.

QUESTION:—The central oil-plunger is designed to care for 17 lb. per sq. in. pressure. Does this not destroy the normal action of the steel springs to that extent?

MR. MCELROY:—If the little pump inside the air-spring were capable of pumping say to a pressure of 100 lb. of air per sq. in., it would pump the air-spring out and extend it; consequently its volumetric efficiency is reduced so that it cannot pump more than to a pressure of 17 lb. per sq. in. That has nothing to do with the operation of the air-spring. The pump diameter is only 5/16 in. The amount of additional restriction due to the action of the pump, that is, to the oil that passes through from the pressure chamber to the lower chamber, is practically negligible.

QUESTION:—Why is it not possible to get the same effect with a flexible steel-spring as with an air-spring?

MR. ELROY:—A flexible steel-spring has a constant scale unless it is built up so that it is progressive in its action. In combination with the steel spring, the air-spring has an increasing scale. If the front suspension of a car were designed to have a spring of a scale equal to that of the air-spring combination at rest position, it would be too flexible and no added resistance would

[6] See *Proceedings of the Institution of Automobile Engineers*, vol. 4, p. 97.

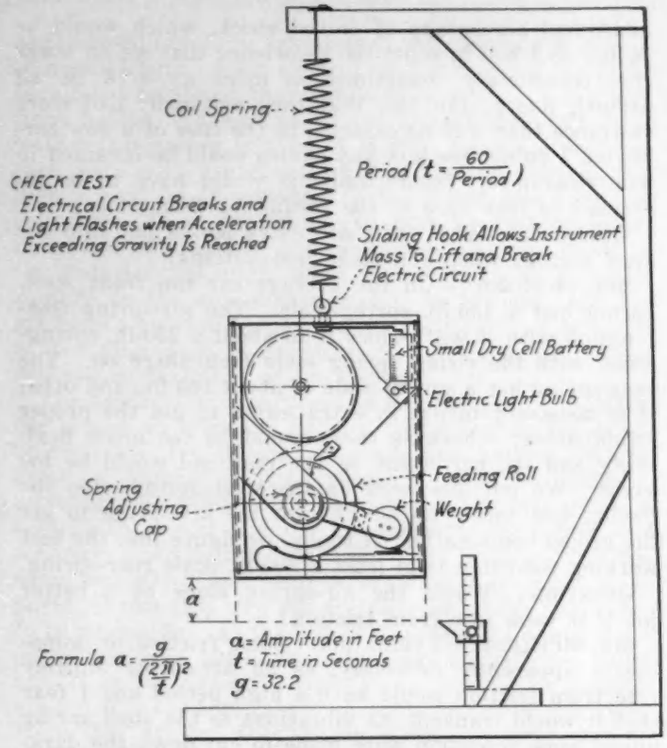

Coil Spring
Period ($t = \frac{60}{\text{Period}}$)
CHECK TEST
Electrical Circuit Breaks and Light Flashes when Acceleration Exceeding Gravity Is Reached
Sliding Hook Allows Instrument Mass To Lift and Break Electric Circuit
Small Dry Cell Battery
Electric Light Bulb
Feeding Roll
Weight
Spring Adjusting Cap
a
Formula $a = \frac{g}{(\frac{2\pi}{t})^2}$
a = Amplitude in Feet
t = Time in Seconds
g = 32.2

FIG. 29—SKETCH SHOWING THE METHOD EMPLOYED IN TESTING AND ADJUSTING THE VIBRATION RECORDER

In Adjusting or Checking-Up the Instrument the Entire Mass Is Suspended on a Coil Spring Having a Definite Period. With a Given Period and a Certain Amplitude the Whole Mass of the Structure Itself Will Have an Acceleration Equal to Gravity. Using the Well-Known Formula for Acceleration, It Is a Simple Matter To Calculate the Amplitude Necessary for Any Given Acceleration. Knowing the Amplitude for That Particular Acceleration, the Mass of the Sprung Instrument Is Set Vibrating and the Adjustment Is Made until the Weight Lifts and Perforates the Tape

be available to take care of the larger shocks. Furthermore, the air-spring and steel-spring combination divides the work so that the deflection or bending of the steel spring is materially reduced, thus increasing its efficiency and length of life.

QUESTION:—How does the air-spring affect side-swaying?

MR. MCELROY:—A more flexible spring-suspension will give more "lean" to the body. The air-spring will accentuate this condition slightly, but the modern car with its low center of gravity has enabled both the steel-spring and the air-spring manufacturers to use springs of greater flexibility without in any way affecting the roadability of the car. Some years ago when the cars were built very high and we were using our old type of spring, side-sway was a common complaint and it was a just complaint; but plenty of cars are on the road today with the original flexible steel-spring equipment that have more lean or side-sway than has a car equipped with air-springs.

QUESTION:—When air-springs on the rear are provided with knuckle-joints to prevent excessive piston and cylinder wear, is not general roadability sacrificed?

MR. MCELROY:—The air-spring that we discontinued 2 years ago had a ball-and-socket rear-shackle construction that necessitated tapering down the end of the spring to attach the ball. We discontinued it because it was not a good mechanical job; when the wear became excessive, it caused an objectionable roll. We now use a direct-connected shackle, very similar to the car shackle connecting the rear cylinder or the rear moving element directly to the spring-eye.

QUESTION:—What of the riding-quality produced by a combination of air-springs and balloon tires?

MR. MCELROY:—We have equipped several cars with air-springs in combination with balloon tires. The results as to riding-quality are very favorable.

QUESTION:—How do you determine the base on which to calculate the percentage of improvement in riding-comfort?

MR. MCELROY:—All our tests are based on comparisons. The instrument shown diagrammatically in Fig. 29 is set to record any vibration exceeding an acceleration of 10 ft. per sec. per sec. In adjusting the instrument or checking it up, we suspend its entire mass on a coil spring having a definite period. With a given period and a certain amplitude, the whole mass of the structure itself will have an acceleration equal to that of gravity. Using the well-known acceleration formula, it is a simple matter to calculate the amplitude necessary for any acceleration, as illustrated in Fig. 29. Knowing the amplitude for that given acceleration, the mass of the spring instrument is set vibrating, and the adjustment is made until the weight lifts and perforates the tape.

QUESTION:—Have you ever made comparative tests by designing new steel-springs having the same approximate flexibility as the combination of the former steel-spring with the air-spring?

MR. MCELROY:—No. I believe that a flexible straight-line-load-curve steel-spring would not be a fair comparison. We have not attempted to build a progressive spring having rising characteristics of the combination load-curve.

QUESTION:—Suppose camber blocks were introduced in the case of the steel spring, so that it would produce the same characteristic as that of your air-spring?

MR. MCELROY:—I presume the camber block is used with a single spring so that, as the load is increased, less of the spring is effective; thus, its stiffness is increased. The Marmon car, I think, has camber blocks between the two cross-springs on the rear. Undoubtedly the load curve of the air-spring and steel-spring combination could be approximated, but the entire deflection would be taken by the free ends of the steel spring, while the combination would have both air-spring and steel-spring deflection, thus giving a counter-spring effect with its subsequent reduction in period and duration of period after absorbing any given shock. It seems to me that the free ends of the camber-block spring would have a higher natural period as the effective length was shortened, even in spite of the fact that the load is increasing. At any rate, I believe that the entire characteristics of an air-spring and steel-spring combination cannot be reproduced with any form of a steel spring alone, whether it be a progressive spring or a camber-block arrangement. It might be done if some form of coil spring were combined with a laminated steel-spring.

QUESTION:—In regard to the curve of the air-spring, if the flexure changes as the load is applied, the spring becomes stiffer; then, it would be in the same class as a built-up or step-up spring. If the test covers the vibration of the air-spring up into the higher pressures, I think it would affect the period just as it would in the step-up spring. In other words, is the period reduced as the load is put on?

MR. MCELROY:—Certainly; it flexes just the same. The period is reduced just as the period of the progressive spring is reduced as the load is put on. Naturally, I meant that the period would be reduced on both of them as the load increased.

Discussion of Papers at the 1924 Annual Meeting

THE discussion of two of the three papers presented at the Passenger-Car Session and of all of the papers presented at the Research Session of the 1924 Annual Meeting is published herewith. In every case an effort has been made to have the authors of the several papers reply to the discussion. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed, and the illustrations, can do so with a minimum of effort.

The discussion following the paper by C. E. Sargent, entitled Essentials of a Successful Constant-Compression Engine, presented at the Passenger-Car Session was published in last month's issue of THE JOURNAL. It is expected that the discussion of the papers presented at the Body Sessions will appear in an early issue.

ENGINE-COOLING SYSTEMS AND RADIATOR OPERATING CHARACTERISTICS

BY N. S. DIAMANT[1]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings.]

ABSTRACT

IN the first part of the paper, a general quantitative comparison of air, water and oil-cooled cylinders is given as it relates to the subject of heat-transfer and temperature drop. Unfortunately, the discussion does not include experimental data, but the assumptions are stated clearly and a large range of values is covered in Table 2 so that any desired values can be chosen. A thorough and comprehensive discussion of the steam or the radio-condenser type of cooling is given under the headings of Steam Cooling Systems, Characteristics of Steam Cooling Systems, Cooling Capacity of Radiators Used To Condense Steam and Present State of Development.

In the second part, an attempt is made to give a thorough but brief discussion of the performance or of the operating characteristics of radiators from the point of view of the car, truck or tractor designer. The cooling of aircraft engines is not considered. A great amount of original material is contained in this second part which should prove not only of direct value and use, but also of indirect value by interesting others in the solution of cooling problems. A summary is given at the end from which some of the salient points can be obtained without making a detailed study of the paper. [Printed in the April, 1924, issue of THE JOURNAL.]

THE DISCUSSION

R. D. MADISON:—I wish to take exception to a statement made by Mr. Diamant in his paper.[2] Conclusion (5) on p. 406, says, "In general, a propeller or curved-blade type fan will draw more air through a high-resistance core than through a low-resistance core." This is entirely misleading since, from the curves shown in Fig. 8, it may be seen that either type of fan, operating at constant speed, will draw more air through a low-resistance core than through one of high-resistance. While the above statement is repeated on p. 402, the subsequent discussion is more to the point. The conclusion should be to the effect that it is possible to draw more air through a low-resistance core with a disc fan than with a propeller fan, both having the same speed; while, on the other hand, it is possible to draw more air through a high-resistance core with a propeller fan than with a disc fan.

N. S. DIAMANT:—I agree with Mr. Madison. My statements do imply comparison of fans at the same speed and it would have been better to have made that clear. The comparison is made and must be made under similar conditions; this is brought out, as stated by Mr. Madison, in the discussion and the numerical examples that follow on p. 402.

QUESTION:—Is not the greater heat-conductivity of the oil offset by its lower specific-heat?

MR. DIAMANT:—That depends upon what advantages you wish to attain and what disadvantages to avoid. Specific-heat will enter to a certain extent, but that probably can be taken care of.

CHAIRMAN T. J. LITLE, JR.:—The specific-heat of oil is only about one-half that of water, is it not?

MR. DIAMANT:—Yes; but no matter what type of cooling you consider, air, water, oil or steam, you will always find that you will have to make compromises. You must have all the data on the subject so that you can make an intelligent compromise. It is not advisable to consider two factors alone, important as they may be, like specific-heat and conductivity.

QUESTION:—Have you any data on the time required to come up to steam?

MR. DIAMANT:—With a steam-cooled engine you come up to steam within a mile or two, depending on the amount of radiation from the engine proper, and also on the load on the engine. If you are going up-hill, naturally you might come up to the steaming temperature very soon; but ordinarily it takes only about a mile or two, or possibly three, to reach boiling.

QUESTION:—Regarding the statement that air-cooling is difficult because of the low heat-flow through the air-film, is it not true that water-cooling also involves the same trouble?

MR. DIAMANT:—In using a radiator we do finally pass the heat to the air, but the radiator is especially designed to do that and nothing else. However, as soon as fins

[1] A.S.A.E.—Consulting engineer, Jamestown Car Parts Mfg. Co., Jamestown, N. Y.

[2] See THE JOURNAL, April, 1924, p. 396.

are put on the cylinder and an attempt is made to get the cylinder to do the cooling, the problem naturally becomes complicated.

I showed two curves in Fig. 1 illustrating very clearly what can be done if you are not handicapped by considerations of engine design but merely want to produce an efficient cooler. The subject of cooling itself is a very fascinating one; it involves the conductivity of the material used, the viscosity and the specific-heat of the cooling medium, the cell size or hydraulic radius and a great many other factors.

QUESTION:—Is a fan necessary with the steam type of cooling?

MR. DIAMANT:—Yes; because when you stop the car, and idle the engine, the same amount of heat will be rejected to the jacket whether the engine is water-cooled or steam-cooled. The temperature of the radiator and consequently the heat transferred to the air may be different in the two cases, but you must have a fan to induce sufficient air to produce the necessary cooling.

QUESTION:—How about alcohol in winter, with its low boiling-point?

MR. DIAMANT:—The engine simply operates at 180 deg. fahr. or so, instead of 212, depending on the strength of the solution. There does not seem to be any engine trouble when alcohol is used.

QUESTION:—What is the heat dissipation at 3 gal. per min. per ft. of width of core?

MR. DAIMANT:—I think there is a little misunderstanding about that. The heat dissipation at 3 gal. per min. per ft. of width of core will depend on the type and the size of the core. In Fig. 10, what I attempted to show is that the characteristic of any radiator is such that, irrespective of type and size, its capacity to dissipate heat increases up to a certain rate of flow, and that beyond this rate the increase in cooling capacity is practically negligible. Therefore, if you are confronted with the problem of what rate of flow to use, or what pump to use, the curve will furnish the answer. In case you want to design or you have designed a thermo-siphon system, Fig. 10 will tell you the extent to which you have handicapped the radiator.

QUESTION:—At what car-speed must the water-flow that the author specifies be obtained?

MR. DIAMANT:—I do not know exactly how to answer that question. However, I must say that I did not intend to specify any rate of water-flow. I merely stated as a matter of information that almost all present-day radiators show a maximum cooling-capacity at about 3 gal. per min. per ft. of width of core per in. of depth of core. Thus, at a given air-flow, if a radiator 2 in. deep and 2 ft. wide dissipates 1000 B.t.u. per min. per 100-deg. fahr. temperature-difference, with a water-flow of 3 x 2 x 2 = 12 gal. per min., it will dissipate less than 1000 below 12 gal. per min., but it will not dissipate much more than 1000 at rates of water-flow higher than 12 gal. per min. So, in answer to the question I might say that the pump should be designed so that at the particular car-speed at which it is hardest to cool the engine the water-flow should be, if possible, equal to or more than three times the depth of the core in inches multiplied by the width of the core in feet, so that the radiator can work at its maximum cooling-capacity.

QUESTION:—Are the types of fan mentioned exactly comparable as to size, pitch, power and consumption?

MR. DIAMANT:—Yes; absolutely as to size, but the pitch and power consumption vary according to the type; one is a propeller and the other a disc type.

QUESTION:—What is the most efficient speed for passing air through the radiator core under average operating conditions.

MR. DIAMANT:—At a car speed of 25 m. p. h., the amount of air flowing through the radiator will depend on the resistance of the radiator. If you take out the radiator and put in place of it a wire screen or a cheesecloth the air-flow will depend upon the resistance of the screen. The relation between air-resistance and air-flow is given by the curves of Fig. 7. The most efficient radiator or screen would be one having zero resistance, allowing an air-flow through it equal to the speed of the car.

QUESTION:—How does the rate of heat-dissipation per unit of frontal area vary with the depth of the core?

MR. DIAMANT:—In general, it follows a curve that falls below a straight-line relation; that is, doubling the depth of a core doubles the radiating surface but does not exactly double the heat dissipation; if 1 sq. in. of surface dissipates a certain amount of heat, that same square inch of surface will dissipate less if the depth of the radiator is increased. I do not know the reason for this. Some very interesting theoretical work could be done along this line.

QUESTION:—Is there any advantage in going beyond a certain depth of core, and what depth is recommended?

MR. DIAMANT:—That is practically the same question in another form. If you are designing a new radiator and want to know whether it is to be 1, 2 or 3 in. in depth, that cannot be answered offhand because the question is not one of depth alone but of cell-size and many other factors.

CHAIRMAN LITLE:—In the manufacture or the design of a radiator, as I understand it, you might add another inch to the depth, yet get very little additional cooling, and at the same time add a large amount of copper. Every radiator designer should be able to answer that question for the car designer.

QUESTION:—How does the rate of heat-dissipation per unit of frontal area vary with the core-depth?

MR. DIAMANT:—It varies according to a curve that can be expressed as follows: Heat-dissipation equals a constant times the depth raised to the nth power, where n is less than unity.

QUESTION:—What are the advantages of the thermostatically controlled water-cooled radiator of the present day as compared with a steam-cooled system operating at the same temperature?

MR. DIAMANT:—So far as the engine is concerned, it will not know the difference; it is a question of which is cheaper or which is better adapted to the particular design under consideration.

CHAIRMAN LITLE:—What is the difference between the condensing capacity of a given radiator with steam-cooling and its cooling capacity with water-cooling? How much more or how much less copper will be necessary?

MR. DIAMANT:—Less copper will be necessary as determined by the expression (170—80) (212—80) = 0.68. According to this expression you will need 68 per cent as much copper when the radiator is at 212 deg. fahr. and the air temperature is 80 deg. fahr. as you will need when the arithmetic mean temperature of the top and the bottom of the radiator is 170 deg. fahr. and the air temperature and the heat rejected to the jacket remain the same. The reason for this is that the cooling capacity of a radiator is directly proportional to the temperature-difference between the mean radiator-temperature and that of the air.

CHAIRMAN LITLE:—In other words, you are getting

ready to cut the price of radiators, if they use steam-cooling?

MR. DIAMANT:—Yes, so far as radiator size is concerned.

F. G. KLOCK:—We recently made some tests of oil as a cooling medium in radiators. We have run some cars with oil, with atmospheric temperatures as low as 20 deg. below zero fahr. I find that oil, in addition to giving a quick warming-up of the engine, which is attributable to its low specific-heat has a thermostatic effect. The viscosity of the oil will increase greatly at the lower temperatures and a smaller quantity will be handled by the circulating-pump, thereby giving the engine more chance to warm-up quickly in cold weather. In operating at from 10 deg. below zero fahr. to 40 deg. above, the actual variation in the engine temperature was found to be less than 10 deg. Lubrication of the pump-gland by the circulating oil eliminated the leakage trouble we had been having at that point.

We operated at atmospheric temperatures as high as 78 deg. fahr., running comparative tests of oil and water. The average rise with oil was about 13 deg. above that with water, which is not prohibitive. I think that with a good system one could possibly operate all summer with oil.

CHAIRMAN LITLE: It seems to me that water systems are designed so as to be just about adequate to take care of the work. But very few of them are adequate; if you put oil in, you would get into trouble in the summertime.

MR. KLOCK:—Although the oil heats-up more quickly in the jacket, its low specific-heat will enable it to cool off much faster than water in the radiator; in other words, it takes less air-flow through the radiator to cool it down to a given temperature.

CHAIRMAN LITLE:—How about the advantage of maintaining a temperature higher than 212 deg.?

MR. KLOCK: That is to be considered.

CHAIRMAN LITLE: We might expect a little higher economy with oil-cooling.

MR. DIAMANT:—Regarding oil-cooling, I have given in Fig. 3 the heat-transfer at different oil-velocities; it seems to me that what we need is fundamental data of that type. When we know all the necessary physical and chemical characteristics of the oil, we can predict pretty well the advantages and disadvantages of oil-cooling. The curve in Fig. 3 is based on an article by S. E. Derby.[3] The particular oil he tested passed one-tenth as much heat as did the ordinary water-film. This information tells immediately what problems we encounter when we attempt oil-cooling. It does not mean that oil-cooling is impossible or bad; it simply shows what one of the factors of the problem is. With reference to the use of oil in conventional thermo-siphon cooled engines, I have tried ordinary kerosene. Within a few miles the top-tank temperature exceeded 212 deg. fahr., the upper limit of the thermometer. I estimate that it reached 250 deg., although the air temperature was well below 32 deg. I have used kerosene for a whole winter in a pump-cooled job and experienced no trouble.

A MEMBER:—In water-cooling, with either thermo-siphon or pump circulation, when the water begins to boil, the engine begins to detonate. With steam-cooling, why would we not have that detonation all the time?

MR. DIAMANT:—I have seen many engines boil and still not detonate. The majority of the cars in the hands of the public boil considerably, some of them very consistently, and still they give no trouble on account of detonation. Steam-cooling, so far as I have tested it, gives no trouble in that way.

C. W. MCKINLEY:—Engines that boil, then, are steam-cooled?

MR. DIAMANT:—In a way they are steam-cooled. In that connection it may be well to emphasize the fact that in a steam or radio-condenser system, the engine jackets are water-cooled. The temperature of the water is 212 deg. fahr., at atmospheric pressure; steam is given off at the water level above the engine and this steam is led to the radiator and condensed. Hence, in steam-cooling we do not have steam in the jackets, but in the radiator; also there is no danger of the water level being reduced below the cylinder head.

HERBERT CHASE:—The average engine with an ordinary water-cooled system detonates when the water reaches the boiling temperature, probably because the steam is trapped in the jacket. This permits some parts of the cylinder-wall to attain a temperature greatly in excess of the temperature of the water and may result in sufficient back-pressure to prevent a centrifugal pump from continuing to circulate water through the jacket. With steam systems the outlets are designed to pass steam continuously as rapidly as it is formed. This prevents excessive pressure and the circulation is much more rapid. In cases that I myself have witnessed, detonation is avoided.

MR. DIAMANT:—In most steam-systems practically no steam circulates around the jackets, but even in the system referred to by Mr. Chase, in which water as well as steam circulates, detonation is not experienced. If the circulation is sufficiently rapid and no hot-spots are formed, no detonation occurs so far as I know.

CHAIRMAN LITLE:—The cooling is more uniform with steam than with some water systems.

MR. CHASE:—It is more uniform because the temperatures are inherently substantially constant, once the formation of steam begins.

DR. H. C. DICKINSON:—I think that steam-cooling has great possibilities. The point that appeals to me, however, as being of particular interest is the relation that steam and cooling may bear to the crankcase-oil dilution problem, which has been exercising us so much.

The results given in the curves shown by Mr. Warner seem to indicate that the oils that were diluted in service, the average samples from 50 or more cars, all had about the same flash-point, independently of what kind of fuel they were diluted with. That seems to indicate that the range of dilution is determined by the average operating-temperature of the engine. Another point, which indicates the same thing, is that the same cars, the same oils and the same fuels, running in summer and in winter, gave a difference in percentage of dilution and a difference in flash-point that correspond, roughly, to the difference in the operating-temperature.

If the average temperature of operation, or the minimum general operating-temperature, can be kept much higher, undoubtedly that will have a very great bearing on the question of oil-dilution.

As regards steam-cooling, when the Bureau of Standards undertook work on the airplane radiator problem, one question that was raised was as to the ability of radiators to handle steam condensation instead of water-cooling. The problem came up in connection with a proposed steam power plant for aircraft. A considerable amount of work was done on that problem and it was found that all the water-cooled radiators acted very satisfactorily as steam condensers without any difficulty

[3] See *Power*, Aug. 2, 1921, p. 179.

at all; the cooling rates were slightly higher with steam than with water; that is, a given area of radiator acting as a condenser will dissipate slightly more heat per degree of difference in temperature than will the same radiator with a water-flow as high as can be used readily.

So far as the operation of steam in cooling the heated surface is concerned, that is, in taking heat away from the engine surfaces, I feel that what I can say is mostly speculative, but, having thought and worked on heat-transfer problems at one time or another, I may venture to speculate slightly. The rate at which water can be evaporated from a heated surface inside a boiler is, of course, excessively high; that is, the crown sheet of a locomotive boiler, for instance, transfers water into steam at a very high rate, much higher than is ordinarily maintained in transferring heat into water in circulation. So, there seems to be no reason why, if water can be kept in contact with heated surfaces, it should not be possible to maintain at least as high a rate of heat-transfer from the jacket surfaces to the cooling medium, as is possible in circulating-water.

One question which comes up in that connection is that of steam pockets; a common trouble oftentimes, that is responsible for the burning-out or the overheating of a section of a cylinder. This occurred, of course, many times in some of the earlier aircraft-engine designs that we tried out. The question arose whether it would not happen much more persistently with steam-cooling than with water-cooling. It might seem, offhand, that this would be the case. On the other hand, I believe that it would not be, because in the operation of a steam-cooling system the water in contact with the heated surfaces is probably in constant rapid agitation. If steam is being generated, naturally the water is being stirred up rapidly by the escape of steam, and it seems likely that the extreme agitation would prevent such stagnation at any point as would allow overheating on the surface. Of course, what occurs when the surface gets overheated beyond a certain point is the establishing of what is known as the spheroidal state, in which contact between the water and the heated surface no longer exists.

If you attempt to put a drop of water on a very hot stove-lid, the water never touches the stove-lid; it holds its position a long time, not boiling away rapidly. But if the temperature drops slightly to a point where the steam layer underneath the water does not support the water sufficiently, the water drops down in contact with the hot surface and immediately disappears as steam. It is conceivable that the same thing would happen in a steam-cooled engine, but, judging from what I have heard said on the subject and from sheer unadulterated reasoning, I doubt whether this condition is likely to occur in a properly designed cylinder.

MR. DIAMANT:—It is a great pleasure to have Dr. Dickinson contribute to this discussion. I would like to say that the conclusions he calls, modestly, speculations are fully borne out by tests on several steam-cooled engines.

I think considerable time and money can be saved if fundamentals such as are given in the first part of the paper and in Tables 1 and 2 are used in investigating steam-cooling. If proper allowance be made for variations from theory, many conclusions can be arrived at. These will prove to be guides in experimental work and excellent shortcuts to many questions that are bound to come up.

RADIATION CHARACTERISTICS OF THE INTERNAL-COMBUSTION ENGINE

BY THOMAS MIDGLEY, JR.[4] AND H. H. MC CARTY[5]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

RADIATION, although the subject of study for many years, is not yet thoroughly understood. The investigations of von Helmholtz 30 years ago showed that from 10 to 20 per cent of the total heat of combustion is due to radiation; but flames burning in the atmosphere show different characteristics from those subjected to a change of density in a combustion-chamber and the same conclusions do not apply. The possibility of a non-luminous flame's causing loss of heat during and after combustion was first noted by Professor Callendar in 1907. The principal theory as to the source of radiation is that it is due to the vigorous vibration of the gas molecules formed on combustion, and that, like the high-frequency radiations producing light, it is caused by chemical rather than thermal action. It has been shown that radiation emanates almost wholly from the carbon dioxide and the water molecules.

As the total heat given off when a mixture burns in a gas engine is divided into two forms, (*a*) that due to conduction, and (*b*) that due to radiation, special instrumentation was necessary for properly observing them. This consisted of a stroboscope by which the duration of the luminous flame, the characteristic differences in color and brightness at different phases of combustion and the variations of the flame with changes in the quality of the mixture could be noted, and a thermopile for measuring the changes in the radiation of the flame. The investigation covered four fuels, namely, kerosene, kerosene plus 3 cc. of lead per gallon, a high-test gasoline that was free from detonation and a new Navy gasoline that contained 3 cc. of tetra-ethyl lead per gallon. Varying the mixture-ratio, detonation and the distribution of the radiant energy was found to affect the amount of radiant energy produced. It decreases as the mixture-ratio is leaned, or enriched to a comparatively low value; but it increases if the mixture-ratio is made very rich and may even be greater than the maximum occurring at the theoretically correct mixture-ratio; and it varies with the pressure. The conclusion reached is that the radiation produced during internal combustion is a function of the chemical reaction involved to a much greater extent than are merely the temperatures of the gases. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

QUESTION:—As the galvanometer pointer moves forward when you use a very rich mixture, might that not be accounted for partly by the fact that the speed was reduced and there was a constant reduction in the air currents?

THOMAS MIDGLEY, JR.:—The increase would not certainly be caused by the speed being reduced. An

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[5] Jun. S.A.E.—Mechanical research engineer, General Motors Research Corporation, Dayton, Ohio.

evacuated cell is used that cannot be affected by air currents, except after a long time. The purpose of using an evacuated cell is to get rid of all the defects.

QUESTION:—Have you ever made any tests to determine the effect of the compression-pressure upon radiation? Does radiation increase as the compression-pressure increases, so long as the detonation is not present?

MR. MIDGLEY:—To a small degree, yes; but not very much, so long as the detonation is kept out.

C. B. DICKSEE:—Have you made any calculations checking the temperature at detonation? The radiation generally is proportional to the fourth power of the temperature and it might be possible to determine the temperatures by the radiation.

MR. MIDGLEY:—With certain reservations, it is true that the radiation is proportional to the fourth power, but it is not true necessarily in the case of an internal-combustion engine. The way we tried to get at the temperature, but were not successful, was to take the infrared spectrometer curve and take the black-body radiation law and the maximum wave-length, and that is inversely proportional to the maximum temperature; but the difficulty is that the detonation does not hit at the same place; it varies back and forth. The study is detonation alone; you must not have anything else there. The detonation jumps back 0.0002 sec. We do not know where it will jump next time. We went so far as to put an element into the engine cylinder so that the window would open when the detonation occurred, but it was too slow. It is possible to do it theoretically, and practically if some one will develop the delicate instrument that is capable of doing it. I believe that the detonation of the carbon is largely due to the increase in the radiation zone up into the visible range so that you are getting that actual dissipation of energy up in the visible range to a large extent.

QUESTION:—What would you conclude then, from your experiment, that the phenomenon of detonation is due to? Is it a violent combustion or a combustion with increased radiation?

MR. MIDGLEY:—The radiation does not throw much light on what is the cause of detonation.

QUESTION:—Have you studied the effect on radiation of different types of head, such as the L-head and the I-head?

MR. MIDGLEY:—No.

HERBERT CHASE:—If you have been unable to measure the temperature variation, how can you arrive at the amount of energy that is liberated to obtain the data for the curves that you present?

MR. MIDGLEY:—The amount of energy that is liberated is quite independent of the temperature. We measure the energy liberated by the galvanometer deflection, which does not necessarily have any known relationship to the temperature. It is not necessary, in taking the temperature; for example, to run a steam-calorimeter test, you do not need to know what the temperature of the steam is; you just run steam into a bucket of water and label the rise of temperature of the water and it tells you how much the pressure of the superheated steam is. The calorimeter measures how much energy is given out; it makes no difference what temperature you are sending in.

CHAIRMAN R. E. WILSON:—Can you not calibrate in absolute British thermal units?

MR. MIDGLEY:—We attempted to calibrate this particular apparatus and I think our calibration was reasonably satisfactory. However, to measure the actual number of British thermal units coming out of the cylinder, we could measure the number that struck the thermocouple, but then we get into a very complex problem as to how many of those we charge that are striking the cylinder-wall. Our best estimate was approximately 25 per cent, but it was more in the nature of an estimate than an absolute measure. It certainly was more than 15 per cent, but there is a rather complicated geometrical problem to translate, although the instrument is calibrated to translate that into just what is striking the walls of the cylinder-head.

F. E. MOSKOVICS:—Would you carry on the curve, which you did not make, of the loss of radiant energy on the lean side, and then would you venture an opinion as to the reason for the drop up to 60 per cent on the lean side? Of course, the rise is obvious, but I want to know the reason for the sharp drop before the rise?

MR. MIDGLEY:—Yes, there is a fairly tenable theory.

MR. MOSKOVICS:—Then could you plot the lean side? There must be a slight rise on the lean side, too.

MR. MIDGLEY:—The normal dies down both ways. On the lean side you have less stuff in there to burn; your temperature and everything is lower, but as you get on the rich side it is not so obvious why it should drop. We have, from those gases, the possibility of four different radiators in the cylinder. We have carbon dioxide, carbon monoxide, water and free carbon. At the proper maximum power-setting we are getting the maximum of carbon dioxide and the minimum of carbon monoxide; the water remaining practically constant throughout. As we run rich, we increase the carbon monoxide and decrease the carbon dioxide, and it is well known from laboratory experiments that the carbon dioxide is a much better radiator than the carbon monoxide. Having come to the 60-per cent point, you begin to get some free carbon, and the free carbon is by far the best radiator of all; so then the line steps right on up. That is a tenable theory. It has not been proved, but it seems to tie-up pretty well.

One interesting thing in this connection is that, when you take a power curve against mixture-ratio, it comes up and holds constant power up to 60 per cent and then it starts to drop off. You can say that the oxygen that gets into the cylinder is just as much of a force as the number of British thermal units of fuel but, actually, you are driving a certain amount of oxygen out of there and you should calculate a little greater drop than you should get; but, because you decrease the radiation, it holds practically a straight line up to 60 per cent. At that point, everything goes wrong and the power drops off very rapidly.

M. R. WELLS:—You said you had not explained the fact that the addition of the anti-knock solution dropped the curve at one point and not at another. Do you suppose that is due to dissociation, which absorbs energy during the first portion and eventually gives it out after another, lower temperature has been reached?

MR. MIDGLEY:—I have no idea; it may be. It is inconceivable that one molecule of tetra-ethyl lead, for example, in 100,000 molecules of active medium in there should be able to absorb that great big burst of energy and hold it and give it out at a later point. Actually, when that anti-knock material was added, the beam of light with detonation was indicating an increase in the radiation given off. Now, if you have the knocking fuel and then supply the anti-knock material to it, the beam of light comes back; the total energy is just about the same in both cases. So, it is not just absorbing it at one place and giving it off at another, because then it

would mean that the amount of energy would have to be as great as in detonation, but it brings the total back as in normal operation. That is absolutely an unexplored field, and it is very difficult to hazard any sort of a guess on it.

QUESTION:—How does the temperature of the jacket affect radiation?

MR. MIDGLEY:—That has not been investigated as yet.

T. J. LITLE, JR.:—Is it possible that acetylene gas, formed during the propagation of the explosion, accounts for some of these conditions?

MR. MIDGLEY:—In the ordinary bench laboratory flame, we know that acetylene is formed in certain places in the flame. We used a small valve, and we obtained no trace of acetylene. Of course, the valve may not have been any good. Acetylene may have been formed, but we could get no evidence of it.

O. M. BURKHARDT:—A product known as Katalite is used to coat the cylinder-head. Considerable improvement in power has been claimed for it. Will this have an effect on radiation? This coating was applied to aluminum cylinder-heads; under my observation, I found it was giving a slight improvement in power, particularly at high speeds.

MR. MIDGLEY:—We have not been able to find any increase in power with Katalite, and we have seen no reason why we should expect any increase in power with the use of it. So, I do not know how I can answer your question. Of course, I am perfectly willing to be shown, because it would be a very interesting thing if Katalite did do that. I can understand how half the people get an increase in power and the other half get a decrease, because you never get two tests that absolutely check.

QUESTION:—What is the effect of spark-advance on the radiation? In regard to the curve showing the effect of anti-knock on radiation, does its peculiar shape come from using benzol as an anti-knock substance?

MR. MIDGLEY:—No. Benzol and alcohol produce perfectly normal indicator-cards. It is only when you use these materials that are really anti-knock materials, not when you use fuels of higher compression-value. Alcohol gives, for the same power output, slightly less radiation; enough so that you can say, from a theoretical consideration at least, that alcohol will give you a little more power output from the engine than any other fuel that is known, because of the decreased loss due to radiation. I introduce that as an explanation of why Mr. Ricardo got the increases with alcohol he obtained.

QUESTION:—How about the spark-advance?

MR. MIDGLEY:—Radiation increases with the spark-advance until you get the high over-advance; then, it decreases.

WINTER TESTS SHOW GREATER DILUTION WITH HEAVY FUELS

BY JOHN A. C. WARNER*

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings.]

ABSTRACT

BECAUSE the analyses of many samples of new and of diluted crankcase oil had not been completed by the Bureau of Standards when the results of the winter tests were reported at the 1923 Semi-Annual Meeting, the report on these dilution data was delayed. This information has since become available and forms the basis of this paper.

After reviewing the results of the winter tests as already reported, stating the names of the cooperating companies and tabulating the cars and the mileage distribution in the test runs, the author discusses the results of the analyses of fresh crankcase oils and the dilution results before making a comparison between those obtained under summer and under winter conditions.

Dilution versus mileage, the subjects of dilution, viscosity and specific gravity and the distillation of composite oil samples are presented next, followed by comments upon crankcase-oil consumption. Numerous tables and charts are included, and a summary of the results is made. In the appendix, a report is made of a set of parallel runs with both a commercial gasoline and a special winter fuel that was conducted by one of the cooperating companies in addition to the regular tests described in this paper and in the previous report. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

QUESTION:—Is benzol one of the four fuels used?

J. A. C. WARNER:—No.

PHILIP W. DES ROCHES:—Is it true that, in winter, the effect of dilution is somewhat counteracted by the fact that the crankcase oil is cooler, and that we will not have as deleterious an effect from diluted oil when it is kept cold in the crankcase as in summer when the oil is much hotter?

C. W. MCKINLEY:—I have had some experience on that. I do considerable driving around the city but, occasionally, I take about a 200-mile trip. While driving about the city, the pressure of the oil remains up where it should be; in other words, the heat generated is not sufficient to warm-up the oil and lower the viscosity. But on a long run at a fairly high speed, the viscosity decreases so that the pressure will be one-fourth what it was and sometimes even as low as one-eighth. Also, a very great consumption of oil is apparent, and I think this represents the boiling out of the dilution that occurred on the short run.

CHAIRMAN R. E. WILSON:—Discussion might especially be in order on the subject of the relative importance of dirt and dilution. It seems to me that this is especially pertinent in view of the results just described which showed that dilution reached very nearly the maximum at the end of 100 miles, and yet the general experience of the industry seems to be that no serious ill effects are realized until a distance of about 500 miles is reached. This seems to confirm the impression that the accumulation of dirt is possibly fully as important as the viscosity of the oil and that the combination of dirt with a diluted oil is the thing that causes the trouble.

MR. DES ROCHES:—One of the ways of solving the dilution problem is by installing a temporary driving-adjustment upon the carbureter. Some carbureters chokes consist only of a butterfly-valve in the intake passage; this feeds a large volume of gasoline and then, when it is opened up, it gives a lean mixture again. If

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the driver were able to provide a richer mixture during the period in which the engine is becoming entirely warmed-up, he would be able to use the normal running-mixture later. In practice, that is accomplished by the garage man who, in winter, sets the carbureter to run much richer than is really necessary after the engine is warmed-up.

MR. MCKINLEY:—We tested three cars alternately with a choke having a spring-return and with an adjustable auxiliary needle-valve. The mileage with the adjustable auxiliary needle-valve was much less than the mileage attained without it; in other words, the driver would pull the valve out until he got good operation and often would forget to put it back. Much the same thing was true with a choke that did not have a spring-return; the driver would pull it out and perhaps push it in one-half or three-quarters of the way and leave it there. Most of the trouble from the use of a choke or an auxiliary needle-valve is due to the operator's carelessness or forgetfulness.

CONTROL OF DETONATION

BY G. A. YOUNG[7] AND J. H. HOLLOWAY[8]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

INVESTIGATIONS indicate that detonation may be controlled by retarding the rate of combustion by chemicals added to the mixture, which serve to increase its specific heat and prevent excessive temperature, and by reducing the temperature of the walls of the combustion-chamber, so that the temperature of the charge previous to ignition will be lower and thus insure a normal rate of combustion. The present discussion is devoted to methods of controlling the temperature of the charge before and after the mixture enters the combustion-chamber, and before normal ignition occurs. Tests previously made on a poppet-valve engine and on a sleeve-valve engine revealed the impracticability of applying the laboratory methods used at that time to commercial practice and the need of eliminating some of the difficulties inherent in those methods of detonation control. The various changes made in the engine are described, including the specially designed spark-plugs. The conclusions drawn from the results of tests covering a period of 2 years are that, when reasonable care is exercised in maintaining the mixture, the spark-plugs, the valves and the combustion-chamber at the proper temperature, a compression-pressure of 125 lb. per sq. in. can be used without detonation by the addition of a small amount of anti-knock compound to the fuel with enough increase in the efficiency of the engine to warrant the additional expense. [Printed in the April, 1924, issue of THE JOURNAL.]

THE DISCUSSION

G. A. YOUNG:—What we tried to do a year ago was to eliminate what we thought were some of the things creating knock. We did that by a specially designed apparatus that was somewhat crude but taught us the story we were after. In this year's investigation our object was to take the lessons we had learned last year, redesign some of our apparatus, and make it applicable to the engine so that the engine could be placed in the chassis and do road-work. That is what we have done. There is nothing on the engine that we have run the the tests on this year that cannot be put right on the road and tested out. The results of this year's investigation, as well as those of last year, together with the various tables, curves, and so forth, are being prepared for a bulletin to be issued by the Engineering Experiment Station.

C. E. SARGENT:—The constant compression obtained and described in this paper is not fundamentally new. Twenty or more years ago the Nurnberg Company and the John Cockerill & Son Co. of Belgium built internal-combustion constant-compression engines, the speed of which was controlled by varying the gas content, by admitting air at the beginning of the induction stroke and gas later in proportion to the mean effective pressure desired. The system works very well with a dry gas but not at all satisfactorily with present-day liquid-fuel, as the agitation required to volatilize it eliminates the stratification necessary to the cycle.

QUESTION:—Where can the special spark-plugs described be secured?

J. H. HOLLOWAY:—We made only enough spark-plugs for our own use.

QUESTION:—Does not a porcelain or ignition point induce preignition or detonation?

MR. HOLLOWAY:—Both, depending upon the temperature.

QUESTION:—What are the comparative values of mica, pyrex glass and porcelain for spark-plugs, particularly for high-compression engines?

MR. HOLLOWAY:—We do not know anything about the qualities of pyrex glass, but we have worked somewhat with mica and with porcelain. It seems that the heat is dissipated a little better with porcelain than with mica. The porcelain seems to stand up well if a good grade is used. However, the kinds of porcelain employed differ considerably. I have run some tests on that particular point and have some curves that are available for those who would like to look at them.

QUESTION:—Have you tried spark-plugs with check-valves to admit air on the suction stroke for cooling?

MR. HOLLOWAY:—We have not.

QUESTION:—Did the long intercooler require more gasoline for acceleration than the shorter manifold?

MR. HOLLOWAY:—This refers to the distributing system. We did not run any acceleration tests. If any difference existed, apparently it was small.

QUESTION:—Does the length of the water-jacket below the combustion-chamber have any effect on detonation control?

MR. HOLLOWAY:—Not so far as I can see.

QUESTION:—Would not a short water-jacket tend to make for more uniform cylinder-temperatures, and cannot a higher average-temperature be carried if the temperatures are more uniform? Would air-cooling the lower part of the cylinder barrels in lieu of water-cooling be practicable?

MR. HOLLOWAY:—I think not, because we must dissipate the heat in the piston, and it is through the rings

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and the cylinder wall that it is dissipated; I think that to keep the temperature of the piston low we should have good cooling of the cylinder barrel.

QUESTION:—With long manifolds around the front of the engine, was any indication of loading or lag in acceleration or uneven distribution noticed?

MR. HOLLOWAY:—I think not.

QUESTION:—What effect would change in atmospheric temperature have on operation, as regards summer and winter temperatures?

MR. HOLLOWAY:—I have no data to offer on that, but it is reasonable to believe that the mixture would be cooled considerably more in the winter time than in the summer, if no means of regulating the temperature of the radiator were available. Of course, the temperature of the air passing through the radiator affects this condition.

QUESTION:—If the charge is dry, why is the section of the intercooler square?

MR. HOLLOWAY:—We did not have a dry charge under all conditions. We did not produce that condition in the way we should have liked. This section of the intercooler was easily made of aluminum, with ribs, with the idea that more intimate contact of the fuel and the air would be possible if there were liquid particles.

QUESTION:—Were you satisfied with the acceleration when using the cool mixture?

MR. HOLLOWAY:—We did not have so relatively cool a mixture, but the acceleration, I should say, was fairly good. With this particular carbureter, to get the mixture as we wanted it, it seemed to be necessary to eliminate the economizer action.

QUESTION:—How was the automatic spark-control operated?

MR. HOLLOWAY:—It was operated through the pressure in the inlet-manifold acting against the plunger and the spring.

QUESTION:—What is the maximum difference in the compression-pressure that is permissible under the best spark-plug conditions alone?

MR. HOLLOWAY:—I should say about 30 to 40 lb. per sq. in.

QUESTION:—What is the maximum burning-pressure for a given compression-pressure? "Atomic vibration" is the theory offered; that detonation results from the free movement of atoms after the molecule has broken down.

MR. HOLLOWAY:—According to my idea, first we must ignite the charge in some way and produce ignition throughout all the charge before it will burn. If we assume that we have a nucleus and electrons flowing around in orbits in different directions, we shall have another nucleus with electrons flowing around it. If by raising the temperature we increase the extent of the electronic travel and increase the speed of travel, after the electrons reach a certain magnitude or distance of travel, ignition will be facilitated throughout the whole charge. As this kinetic energy of the molecules is in direct proportion to the absolute temperature, a larger movement of these molecules, or atoms, which would facilitate ignition throughout the charge, will occur.

It seems that, after a certain critical temperature has been reached, depending on the combination of fuel, the distance traveled, or the velocity, will be greatly increased, and combustion facilitated to the point where we get detonation.

QUESTION:—Were tests run long enough to develop a normal coat of carbon?

MR. HOLLOWAY:—Yes.

QUESTION:—What compression-pressure is possible with aluminum pistons as against iron?

MR. HOLLOWAY:—Approximately 25 to 30 lb. increase over the cast-iron pistons is allowable with the alloy, with a normal amount of carbon cleaning.

QUESTION:—How can cool dry mixtures be obtained? These terms are rather contradictory.

MR. HOLLOWAY:—"Cool dry mixtures" is a relative term; relatively cool, of course; about 125 deg. fahr.

QUESTION:—What gain in thermal efficiency have you obtained by the use of high compression?

MR. HOLLOWAY:—The thermal efficiency in this test was a little less than that obtained last year, the difference probably being made up by the driving of accessories, water-pump, fan and generator. The highest thermal-efficiency was about 26 per cent.

QUESTION:—What is the difference in British thermal units for brake horsepower in the cooling-water between high and low compression; also what is the number of British thermal units given out by the engine?

MR. HOLLOWAY:—Very little increase.

QUESTION:—Will you give more details concerning the special ribbing of the cylinder-head to induce better cooling?

MR. HOLLOWAY:—If reference is made to the new aluminum heads that are now being developed, the Knight-type head is a cylindrically shaped pocket; it might be expected that the fins or rings projecting into the water space help to dissipate the heat from the head.

QUESTION:—What has been accomplished in controlling the temperature of the intake air by a thermostat?

MR. HOLLOWAY:—We have not done anything on that.

QUESTION:—In your opinion, what point in the combustion-chamber is most at fault in causing detonation in production engines?

MR. HOLLOWAY:—I would say that the two things are the spark-plugs and the exhaust-valves.

QUESTION:—If the thermo-siphon cooling-system is properly designed, is it not as effective as a pump system?

MR. HOLLOWAY:—I do not think so. Many will probably take exception to that statement, but this is my reason: In a pump-circulating system a definite flow occurs, a little more than in the thermo-siphon system; and the velocity over the surface to be cooled is also higher, if the proper piping is provided; the higher velocities, of course, brush off the steam bubbles more readily and the result is a lower temperature of the surface, the result that we are after.

QUESTION:—Will additional dilution of the charge with exhaust gas to reduce the flame-temperature, as described by Ricardo, allow the maximum compression with commercial fuel, or as high compression as is allowed with doped fuel?

MR. HOLLOWAY:—I think not.

QUESTION:—What effect did high compression have on the life of the bearings and on vibration, as compared with lower compression?

MR. HOLLOWAY:—I believe that high compression has a deleterious effect on bearings. Apparently we had to adjust the bearings unusually frequently. As to vibration, it might be slightly more. Some condition of rough running is noticeable.

CHAIRMAN T. J. LITLE, JR.:—Is the rough running more pronounced at certain periods, or does it continue throughout the entire range?

MR. HOLLOWAY:—After you have changed over from the normal-compression to the high-compression heads,

you can notice a slight roughness that was not perceptible before, throughout the entire range.

QUESTION:—Did high compression tend to make standard ignition more effective than did low compression?

MR. HOLLOWAY:—I cannot say that it did.

QUESTION:—What do you believe to be the best position for a commercial spark-plug in high-compression heads?

MR. HOLLOWAY:—When high compression is used, an effort should be made to slow-down combustion. If I understand turbulence correctly, its effect is to speed-up combustion. If the spark-plug is located in an off-corner, where the ignition is good, the flame would probably take a longer time-interval to travel. Turbulence has the fine quality of cooling the hot parts or points that project into the highly agitated charge and thus prevents hot-spots and renders the temperature throughout the charge more uniform.

CHAIRMAN LITLE:—I should like to inquire regarding a possible chemical change during the propagation of the explosion. Do you believe that some of the peculiar knocks we get may be caused by the production of acetylene during the explosion, accounting for the peculiar little peaks in the curve that we see sometimes?

MR. HOLLOWAY:—I have always had the notion that detonation, as we observe it, is due to almost instantaneous combustion of some sort. I used to think of detonation as a charge that was at nearly the critical temperature; that when a part of the charge was set off near the point of ignition, it raised the pressure and therefore the temperature of the whole charge, until it all exploded. But I do not now believe that this is the case. If one of the special spark-plugs is removed and a commercial spark-plug substituted, the temperature in the cylinder will drop temporarily but detonation will result. So, it seems not to be a case of working close to the critical temperature, but of part of the charge exploding from the hot spark-plug setting off the rest through an increase of pressure and high temperature.

MR. YOUNG:—Our idea of hot-spotting was to get as nearly permanent a gas as we could after the fuel had gone through the carbureter. We found, when that had been done, that our mixture was too hot and caused knocking. After putting the fuel through the intercooler and then sending it into the cylinder, it was found to be cool enough so that when the normal compression-pressure was increased from 75 to 125 lb. per sq. in. we did away with knocking. The increase in the thermal efficiency, based upon the brake horsepower, was about 25 per cent, and the increase in the power capacity of the engine, due to increasing the compression-pressure from 75 to 125 lb. per sq. in., was about 26 per cent.

C. W. MCKINLEY:—What was the maximum horsepower developed?

MR. HOLLOWAY:—The horsepower varied considerably with the mixture-ratio. If we used a mixture-ratio for high power, we had some increase in horsepower over the original horsepower as developed under standard conditions, but if we ran a lean enough mixture for high economy, the horsepower fell off greatly.

P. S. TICE:—I think we ought to elaborate on this question, because many data are to the effect that what we really ought to do is equalize the temperature distribution in the cylinder; and most of the expedients followed by Mr. Holloway accomplished that thing.

J. H. HUNT:—I should like to ask whether Mr. Holloway is certain that when he changed from the special spark-plugs to the standard spark-plugs and got detonation, he did not at the same time have preignition and get his result because of the advancing of the spark?

MR. HOLLOWAY:—The ignition was held constant; that is, we did not change the advance.

MR. HUNT:—Did you have any other evidence than detonation that the condition was changed?

MR. HOLLOWAY:—I think not; because, with these special spark-plugs, if you shut off the ignition, the engine will immediately die; and if you are working under high or low conditions and the engine is very hot, it will continue to run with standard spark-plugs.

MR. HUNT:—Then you are getting self-ignition. This self-ignition, if sufficient to enable the engine to run with the ignition cut-off, may very possibly be so early as to come earlier than the time for which the electric ignition is set. Under this situation the detonation would be due to preignition. The point I wish to make is that the detonation is only indirectly due to the spark-plugs; it is possibly directly due to the time of the ignition of the charge.

THE FINE ARTS

A MODERN university is fundamentally a servant of the Nation. It must sense the Nation's educational needs at least a generation before the results of its services can be effected. In the growth of the American Nation, whose history to date has been chiefly marked by the spirit of the pioneer and an extraordinarily rapid development, the fine arts have played but a small part compared with contemporaneous development in Europe. This is but natural, for the physical conquest of a continent largely precludes the growth of other influences that tend to make for culture.

But we are rapidly emerging, if we have not already emerged, from the great era of expansion, and, while there remain abundant opportunities, the greater part of the present national development is of a permanent nature. It is time that America should not only evidence the attainment of maturity, but also that her people should have the benefits resulting from it. The opportunities and obligations to further these ends primarily fall on the modern university.

GEORGE R. BEAMER

IT is again our sad duty to add another name to the list of deceased members and to record the death on July 15, 1924, of George R. Beamer, sales manager of the Detroit branch of the United States Gauge Co., New York City, at the age of 54 years. He resided in Detroit but was buried at Redford, Mich. His wife and a daughter survive him.

Mr. Beamer was born, July 7, 1870, in the province of Ontario, Canada, and received a general education that was supplemented by experience along commercial lines. Eventually, he became connected with the United States Gauge Co. and had been in its service for many years. He was elected to Associate Member grade, Feb. 24, 1914.

Trunk-Highway Motor-Traffic

By William G. Sloan[1]

Metropolitan Section Paper *Illustrated with* Photographs and Drawings

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

Social and industrial progress has been revolutionized within the last few years, and transportation mediums have been taxed beyond their capacity in endeavoring to meet the demands made upon them. Many miles of new track have been constructed and old lines have been rehabilitated. In many respects the problems of the motor truck are similar to those of the railroad. The function of the motor truck in handling short-haul business is recognized, but adequate facilities must be provided for operating it or its advantages will be lost. When a highway becomes so congested that it cannot take care of the traffic it is of no more benefit to a district than is an unimproved highway. The arrested development of the New Jersey coast, the location of many summer resorts, is laid to this condition. In certain Middle Western States there is one automobile to every five persons, and the flattening of the curve indicates that within 10 or 15 years the ratio will be one to four. Inasmuch as the traffic in any locality has been found to vary somewhere between the one-half power and the first power of the number of vehicles licensed, the density of traffic in 14 years will be approximately 2.7 times its present volume; but the ratio of trucks to passenger cars will increase.

To provide for the anticipated increase of congestion at both ends of the highway between Jersey City and Camden with the opening of the Hudson River vehicular tunnel and the completion of the Philadelphia-Camden bridge, improvements in the approaches have been proposed. The improvement at the northern end, passing through Jersey City in an open cut and around Newark and Elizabeth to avoid local traffic, will extend for 13 miles from the tunnel to a point beyond the city of Elizabeth, where it will connect with the State highway route. Gradients and curves have been reduced so that trucks can be operated without changing gears. The hourly traffic-count over this route is expected to be about 5500 vehicles, or about twice the number passing 42nd Street on Fifth Avenue. By eliminating grade-crossings and reducing the rise and fall of the highway by 20 ft. it is estimated that a saving in the fuel consumption will be effected which will be sufficient to pay the cost of constructing the highway; traffic also will be speeded-up.

The surface of the highway, which will be of granite blocks laid on a concrete base, will have a minimum width of 50 ft. At the Camden end, where the traffic will be heavier because of the converging of three State highways, the width will be 80 ft. Lack of money alone has so far prevented the proper extension of highways. The total amount available in New Jersey per year from bond issues, licenses and Federal aid is about $19,000,000. Compared with this the people of the State spend annually $78,000,000 for gasoline and tires and have spent not less than $440,000,000 for the vehicles themselves.

Experience must be the controlling factor in building roads, owing to the variable conditions. Some soils that are satisfactory when dry become unsuitable when moist; these become more stable by the addition of Portland cement or lime. A layer of pervious material interposed between the subbase and the bottom of the pavement spreads the load over a greater area and reduces the pressure per unit area. Concrete is the only material that will withstand the heaviest traffic, but it possesses elasticity and undergoes stresses due to moving loads and to changes of temperature and moisture, so that expansion-joints are necessary at intervals of 60 ft. Heat tends to curl the edges up in the daytime and down at night. This expansion and contraction, although very small, is sufficient to weaken the pavement enough so that pieces may be broken off by a heavy truck. When this occurs the subsequent destruction of the pavement is rapid. To prevent it the sides of the road are made thicker than the center. A longitudinal joint along the center line lessens the liability to crack.

Three types of wearing surface are in use at the present time; (*a*) bituminous mixtures, (*b*) concrete and (*c*) granite block. Bitumin is sufficiently strong for light loads but is slippery in wet weather; concrete must be laid monolithically with the base and is not renewable, but will last for 15 to 20 years; for the heaviest traffic granite blocks are the best.

Good roads will produce a saving of approximately 25 per cent in the annual expenditure for gasoline and tires. When based on an operating cost of 10 cents per car-mile, the capitalized value of saving 1 ft. of the rise and fall of a road without increasing the distance is shown to vary from $2.40 to $19.00 per 100 vehicles per day, for grades varying from 2 to 5 per cent. Capitalized at 5 per cent this would mean a saving of from $47.50 to $380.00 per year. Figured in the same way, the saving of 20 ft. in the rise and fall of the highway through Jersey City would amount to $79,930, which, when capitalized at 5 per cent, would amount to $1,500,000.

THE present amazing progress is unprecedented in the world's history, for in the lifetime of men still living so extensive changes have occurred that the social and industrial life of the Country has practically been revolutionized. To keep pace with the development, the transportation mediums have been taxed beyond their capacities; and the crying need at the present time is for further improvement of these facilities so that other developments that depend so intimately upon them may advance as they should. To a very considerable extent, the railroads of the Country have met and are meeting the increased demands placed upon them. These increased demands have necessitated not only the construction of additional mileage, but also the reconstruction of other mileage, in order that the burden upon them could be carried at all. The further reconstruction and betterment of considerable parts of their systems has involved the expenditure of enormous sums of money to effect economy of operation, such expenditures being justified in every case because the saving in operating expense has been sufficient to take care of the capital investment required.

[1] Engineer, New Jersey State Highway Commission, Trenton, N. J.

The development of the motor-vehicle industry has created a situation as regards our highways that involves them in the same problem that the railroad companies are endeavoring to solve; and the experience of the railroad companies may well be used to advantage by those who are working out our highway problems. As a matter of fact, the two mediums of transportation are now closely related and are fast becoming more so.

The railroad companies realize the fact that much of their short-haul business can be handled more economically and with greater convenience to the consumer by motor trucks operating over the highways. It is unnecessary for me to quote figures indicating the astounding growth of the motor-vehicle industry, as these figures are well known, as is also the fact that the development of the highways has in no way been commensurate with the demands of the motor-vehicle industry and its output.

Effect on Property Values

The development of the motor-vehicle industry, together with such improvements of the highways as have been made, has resulted in a very great increase in property values. These values will not increase farther and in all probability will decrease unless adequate highway facilities are provided. A striking example is afforded by the development of the New Jersey coast, where, from Sandy Hook to Cape May, resorts have been developed having an assessed valuation at the present time of some $300,000,000. The traffic on the highways leading

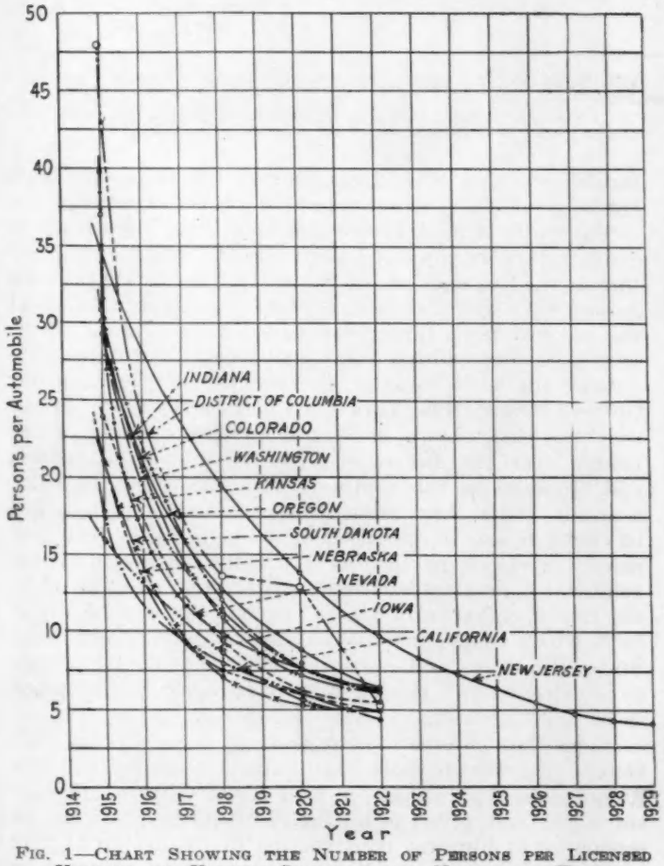

Fig. 1—Chart Showing the Number of Persons per Licensed Vehicle for Various States over a Number of Years

An Examination of the Curves Shows That in 1922 in the Middle Western States One Car Has Been Licensed for Approximately Every Five Persons and That If the Curves Are Projected into the Future as Was Done in the Case of New Jersey They Will Flatten Out at the Point Corresponding to One Automobile for Every Four Persons

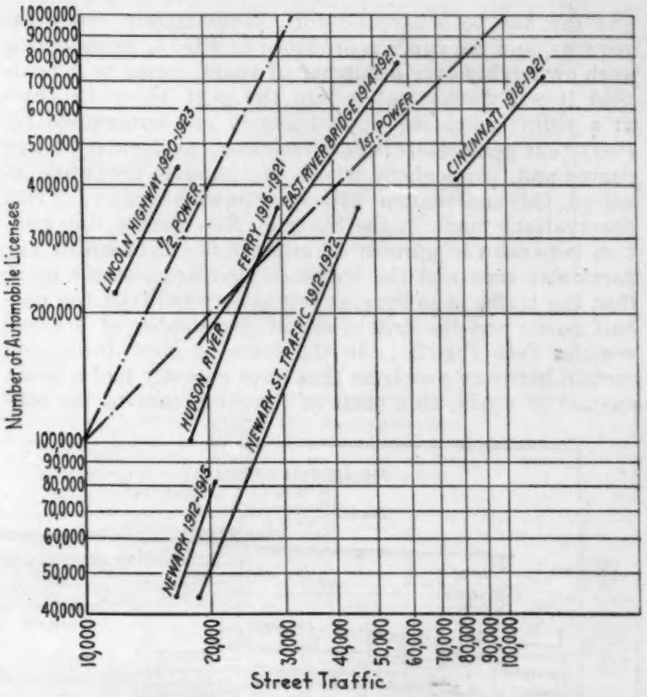

Fig. 2—Relation of Automobile Licenses to Street Traffic

From Observations Made in the State of New Jersey It Was Found That the Traffic Count Varied Somewhere between the One-Half and the First Power of the Number of Licensed Vehicles. Figuring on This Basis the Conclusion Is Reached That the Traffic in 1937 Will Be Approximately 2.7 Times the Present Volume and That the Proportionate Increase of Truck Traffic Would be Greater than That of Passenger Cars

to these resorts has become so congested that the highways have practically reached the limit of their capacity and further development will certainly be arrested on that account. I am of the opinion that, unless additional highway facilities are provided, an actual decrease in property values will occur; for highways, even though they may be well constructed and kept in perfect repair, become so congested by reason of the traffic imposed upon them that they do not offer reasonably good facilities for the movement of traffic over them and in reality are no better than unimproved highways so far as their benefit to the user or to the district served by them is concerned. This same thing is true in the case of industrial and manufacturing centers.

A further interesting example of the effect of the improvement of highways on property value is afforded by the increase in the value of rural lands. A tabulation of land values would show a more or less definite correlation of the values with the distances of the land from improved highways, which is due, of course, entirely to the degree of accessibility of the lands to the community centers.

Probable Future Conditions

Assuming that adequate highway facilities will be provided, it is interesting to speculate as to what the probable future traffic on these highways will be as regards both character and amount. I say speculate, because I believe he is a bold man who will venture to predict what the course of events will be for any considerable period of time in this day of rapid change and development. We can, however, on the basis of the present trend of the increase in motor-vehicle ownership and use, arrive at general figures in connection with them. A survey of motor-vehicle ownership throughout the Country shows that in certain Middle Western States

one car has been licensed for approximately every five persons, and the curve reproduced in Fig. 1, representing such ownership over a number of years, seems to indicate that it will flatten out within the next 10 or 15 years at a point indicating approximately one automobile for every four persons. It is possible also to project population curves and, particularly where considerable areas are involved, this can be done with reasonable accuracy. From observations made in the State of New Jersey, the relation between the number of automobiles licensed in any particular area and the traffic in that area, seems to be that the traffic count varies somewhere between the one-half power and the first power of the number of licensed vehicles (see Fig. 2). In the State of New Jersey, on certain highway problems that have recently had a great amount of study, this basis of figuring leads to the conclusion that the traffic in 1937, approximately 14 years hence, will be 2.7 times the present volume; and it was considered that the proportionate increase of truck traffic would be greater than that of the passenger car.

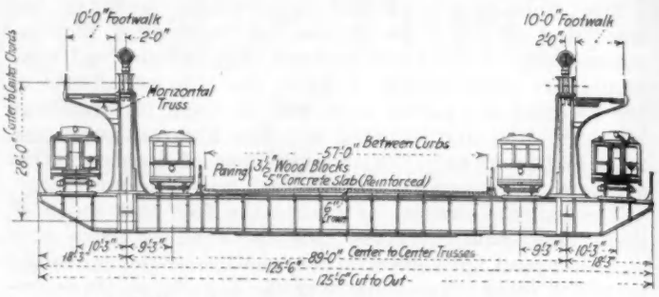

FIG. 5—CROSS-SECTION OF THE MAIN SPAN OF THE DELAWARE RIVER BRIDGE

The Total Width of the Bridge Is 125½ Ft., of Which 57 Ft. Is Utilized as a Roadway for Motor-Vehicle Traffic. Tracks for Trolley-Cars and Subway Trains Are Provided as Well as Two Footpaths

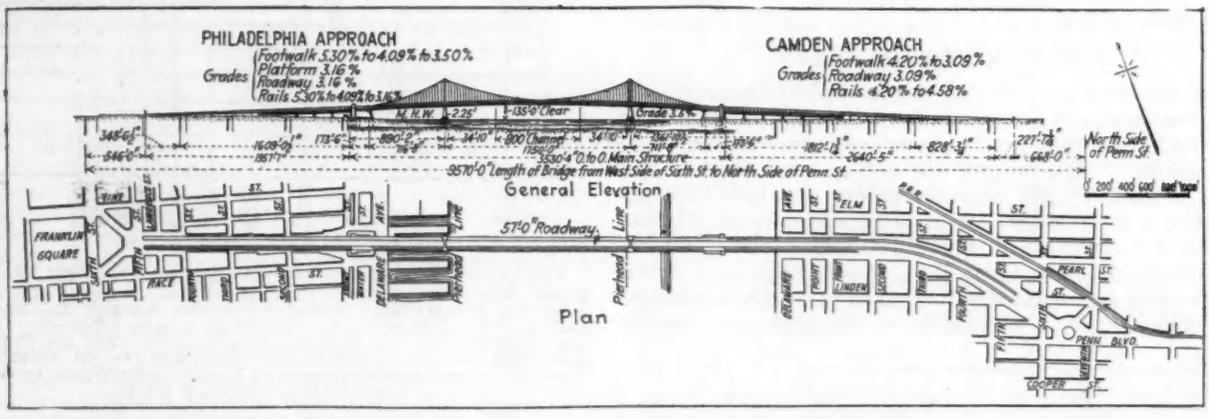

FIG. 4—PLAN VIEW AND ELEVATION OF THE BRIDGE OVER THE DELAWARE RIVER CONNECTING THE CITIES OF CAMDEN AND PHILADELPHIA

This Structure, Which It Is Expected Will Be in Operation in 1926, Has a Total Length of Approximately 9600 Ft. and a Maximum Grade on the Roadway of 3.50 Per Cent

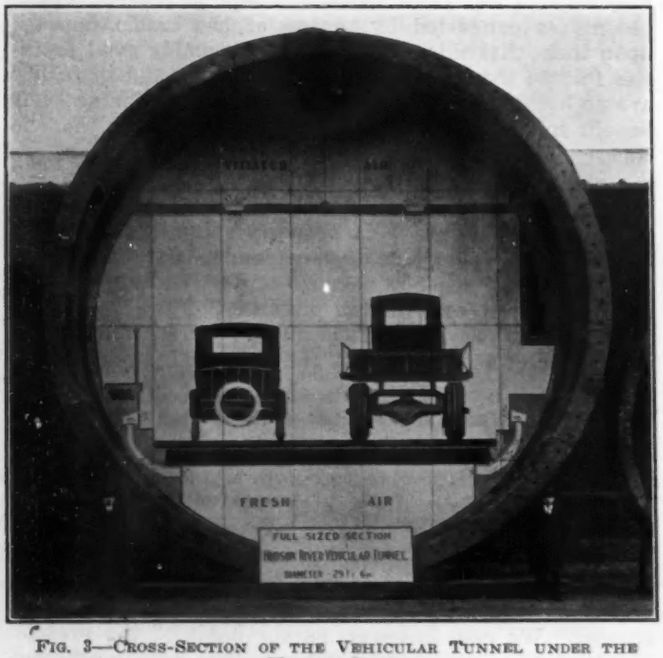

FIG. 3—CROSS-SECTION OF THE VEHICULAR TUNNEL UNDER THE HUDSON RIVER

Two Tubes, Each Large Enough To Accommodate Two Streams of Vehicles, Will Be Constructed. The Ventilating System Provides for the Introduction of Air under Pressure near the Floor and the Vitiated Air Will Be Removed by Suction through Openings in the Roof of the Tube

The traffic studies I have just mentioned were made in connection with proposed plans for the relief of congestion at the two ends of the State Highway route between Jersey City and Camden, a route heavily congested at the present time, largely by motor-truck traffic. Plans have been made with a view to relieving the further congestion that will occur on the opening of the vehicular tunnel between New York City and Jersey City, on the northerly end, shown in Fig. 3, and the opening of the bridge over the Delaware River between Philadelphia and Camden, on the southerly end, illustrated in Figs. 4 and 5. Both these structures, it is contemplated, will be complete and in operation in the year 1926. The proposed improvement leading from the entrance of the vehicular tunnel extends for a distance of 13 miles from the tunnel entrance to a point beyond the city of Elizabeth, where connection will be afforded with the existing State Highway routes. The maximum hourly traffic to be expected over this 13 miles of highway was assumed to be 5500 vehicles.

It may be interesting to note in passing that this volume of traffic is more than twice the traffic on Fifth Avenue at 42nd Street in New York City. Due consideration was given to all the elements involved in the economics of highway construction in the design of this work, the gradients and the curvature were adjusted to allow the safe operation of motor trucks without the necessity for changing gears, and the highway was carried around the congested portions of Newark and Elizabeth, as shown in Fig. 6, in order that its purpose

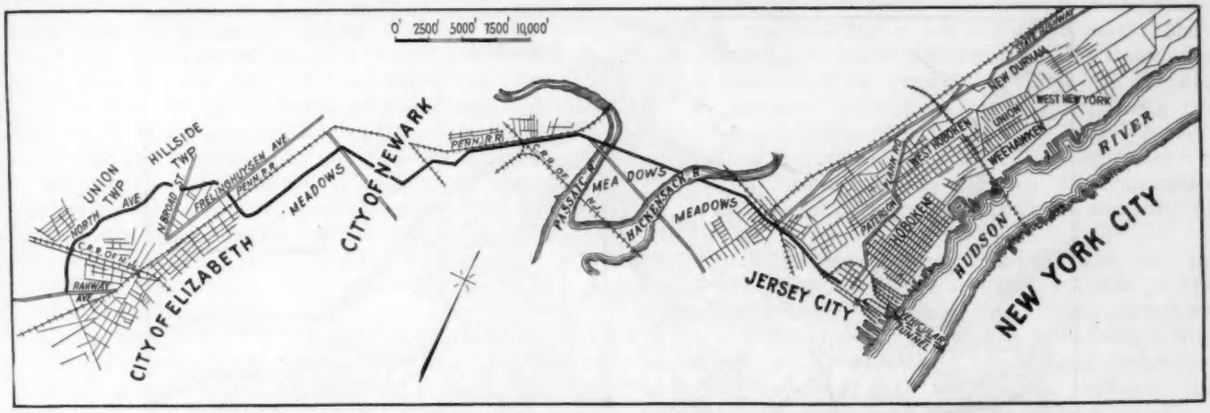

FIG. 6—HOW THE MOTOR-TRUNK TRUCK-HIGHWAY AVOIDS THE CONGESTED PORTIONS OF NEWARK AND ELIZABETH

In Planning This Highway the Gradients and the Curvature Were Adjusted To Allow the Safe Operation of Motor Trucks without the Necessity for Shifting Gears and It Was Deflected around the Centers of These Two Cities So That It Would Serve as a Through-Highway and Not Have Its Efficiency Impaired by the Presence of Strictly Local Traffic

as a through-highway might be served and its efficiency not be impaired by the presence of strictly local traffic.

Through Jersey City, to accomplish the same result, the design carries the highway through an open cut sufficiently below the level of the existing streets to enable them to be carried over by bridges. In addition to the vital advantages gained by the elimination of all grade-crossings, a saving of some 20 ft. in the total rise and fall was effected, as is brought out in Fig. 7, and the fuel saving consequently produced on the large volume of traffic that will be handled by the highway was found to be sufficient, when capitalized, to pay for the cost of the construction, even though the construction of this depressed roadway through Jersey City involved the removal of a large quantity of trap-rock.

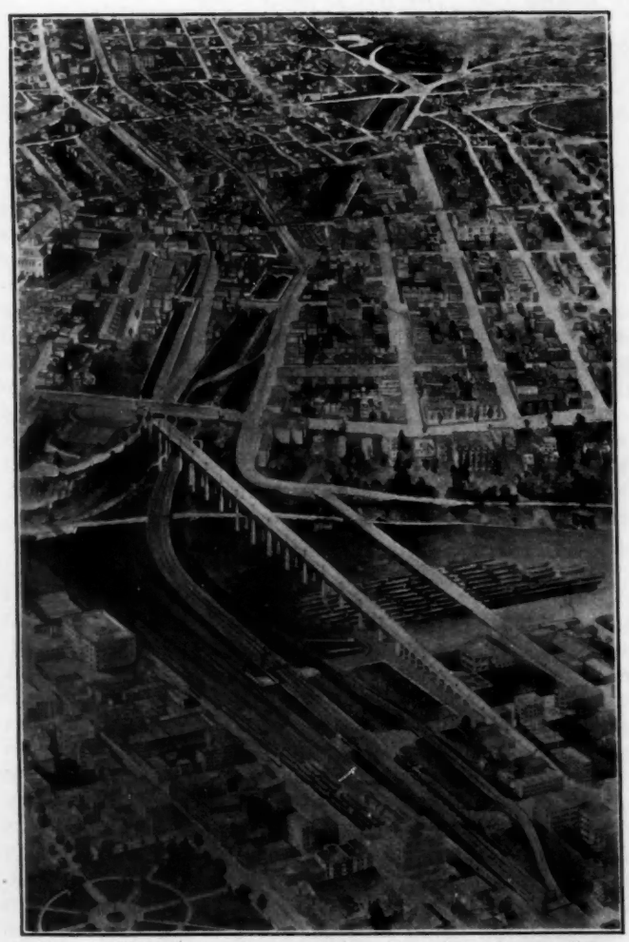

FIG. 7—HOW GRADE CROSSINGS ARE AVOIDED IN JERSEY CITY

The Highway Is Carried through an Open Cut across Which the Streets Are Carried by Bridges. Another Advantage of This Arrangement Is a Saving of 20 Ft. in the Total Rise and Fall with a Consequent Fuel-Saving That If Capitalized Would Be Sufficient To Pay for the Cost of Constructing This Depressed Roadway

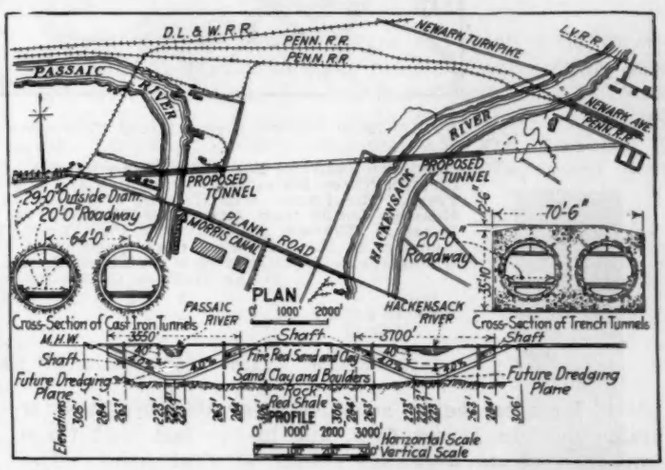

FIG. 8—PLAN OF PROFILE OF THE CROSSINGS AT THE HACKENSACK AND PASSAIC RIVERS

To Obviate the Delays Due to Navigation Twin Tunnels Each Having a 20-Ft. Roadway Will Be Driven under These Two Streams

The elimination of all railroad grade-crossings and, so far as possible, of all grade-crossings with other highways on this route, makes it possible for it to carry the large volume of traffic it will have to bear, and will allow traffic to move safely at a speed that will not only facilitate the moving of through-traffic, but will afford expeditous connections between Jersey City, Newark and other surrounding cities. The plans for this highway contemplate the crossing of the Passaic and the Hackensack Rivers by means of tunnels (see Fig. 8), thus obviating the delays due to navigation. The highway, having a heavy concrete base and a wearing-surface of granite block, is designed with a minimum width of 50 ft. between curbs.

IMPROVEMENTS AT CAMDEN

The improvement of the southern end of the route in the vicinity of Camden was studied and designed along similar lines, the conditions obtaining at that

FIG. 9—MAP SHOWING THE ROADS CONNECTING THE TRUNK HIGHWAY WITH THE DELAWARE RIVER BRIDGE

The Plan Provides for a Belt-Line Outside of the Congested Portion of Camden That Will Connect Three State-Highway Routes and a Connection between the Belt-Line and the Bridge Plaza. The Latter Will Have a Width of 80 Ft. between Curbs and Will Probably Carry Heavier Traffic than Any Other Highway in the State of New Jersey. The Traffic Census Taken in 1923 and the Estimated Peak Traffic for 1933 Are Given in the Following Table, the Numbers in the First Row Corresponding to Those in the Circles on the Map. The Absence of Figures in the Second Row for Points 2, 4, 7, 8 and 12 Indicates That the Road in Question Is To Be Built in Connection with the Delaware River Bridge

Point	1	2	3	4	5	6	7	8	9	10	11	12
Vehicles per Hr. on Basis of												
1923 Census	820	....	350	....	1,010	173	....	....	620	400	320	....
1933 Estimate	2,130	3,500	910	2,700	2,630	453	4,950	5,960	1,610	1,040	830	3,480

point, however, being such as to create even heavier traffic than in Jersey City, due to the fact that three important State highways center at that point. The plans, as drawn, provide for a belt-line, or crescent route, outside the congested portion of the city of Camden, that will connect the three State Highway routes, and also a connection between the belt-line and the bridge plaza. The plaza connection, 2.46 miles in length, which is shown in Fig. 9, will probably carry heavier traffic than any other highway in the State, and is designed with a width of 80 ft. between curbs.

When these improvements have been made, the highway between Jersey City and Camden will, to all intents and purposes, be a motor-truck trunk-highway. Although for the present and probably for some years to come it will be used by both commercial and passenger vehicles, it is probable that ultimately other provisions will have to be made for the lighter cars, in view of the almost certain increase in the use of commercial vehicles between these points. It is unquestionably a fact that other highways for commercial purposes will be required in the State of New Jersey, and thought is already being given to the possibility of their being constructed adjacent to and in connection with the inland-waterways project in certain parts of the State.

The essential consideration in connection with such motor-truck highways is that they shall, so far as possible, lie outside towns and cities and be located so as to reach existing or potential industrial centers. A further consideration is their relation to the railroads, for, as I have previously stated, highways are properly taking the place of the railroads for short-haul distribution. It is conceivable that the railroads may find it to their advantage to construct yards and terminals in the vicinity of the larger centers of population, from which a very large tonnage will be moved by motor trucks direct to its ultimate destination. The question whether such motor-truck distributing systems should be absorbed and become a part of the railroad systems or be handled by others should, it seems to me, be of vital interest to you as motor-truck producers; you should give consideration to it before the railroads have absorbed the business. However, by whomsoever this distribution may be actually effected, the point remains that in locating motor-truck highways, due thought should be given to the fact that this condition will probably exist.

REVENUE AVAILABLE FOR BUILDING ROADS

Highways are constructed with public funds, and it is to a considerable extent the lack of such funds that has placed highway construction throughout the Country in so disadvantageous a position with respect to the increase in the number of motor vehicles that use the highways. The last few years have, however, seen a marked improvement on the part of the counties, the States and the Federal Government toward providing funds for this most essential and vital purpose. Many of the States have authorized bond issues, the proceeds of which are to be devoted to this work and, likewise, in most of the States, the receipts from motor-vehicle licenses, and from other sources of revenue in connection with them, are being set aside for this purpose. At the present time the Federal Government is appropriating approximately $65,000,000 per year to assist the States in carrying out their highway programs. In the aggregate these funds look large but, considering the total mileage of highway over which they must be distributed,

they are entirely inadequate and, in comparison with the amounts of money being paid by the taxpayers for motor vehicles and their operation, are very small. In the State of New Jersey, a bond issue of $40,000,000 has been voted for the construction of the State Highway system; these funds are available at the rate of $8,000,000 per year for 5 years. In addition to the $8,000,000 each year, there are available, for the construction and maintenance of highways, the motor vehicle receipts amounting to approximately $9,000,000 per year, and Federal aid to the amount of $900,000, with possibly $1,000,000 a year from other sources; or a total of approximately $19,000,000.

In comparison with this amount, as is brought out in Fig. 10, the people of the State of New Jersey are expending for the essential items of oil, gasoline and tires approximately $78,000,000 each year, and have expended their money to the amount of not less than $440,000,000 for motor vehicles now licensed in the State.

As regards the matter of the design and construction of highways, the object sought is to secure a structure that shall be the shortest practicable, consistent with economy, between the points to be reached, and shall have only such gradients and curvature as will allow economical operation, and shall present a hard smooth durable surface for vehicular traffic. Obviously, owing to the variable conditions of the soil on which such a structure must be founded, its design does not lend itself to scientific analysis; and, in my opinion, the proper design of highways will be determined largely by experience rather than by strictly engineering calculation. I do not mean that the very valuable information resulting from the tests that have been conducted and the research work that has been carried out by several of the States and by the Federal Government should be ignored, but rather that these results should have our careful thought and study and be used in connection with the information gained from careful observation of the several types of pavement that we are now constructing, as developed in their actual use.

Requirements for Satisfactory Highways

The prerequisite to a satisfactory highway is a subbase sufficiently firm to carry safely the loads transmitted to it through the pavement. Any of our soils, when in a dry state, is capable of doing this satisfactorily, but many of them, as the water content increases, become more or less plastic and consequently unsuitable. It becomes necessary, therefore, to make such provision for drainage as will keep the subbase in a satisfactory condition. In most soils this can be accomplished by drainage structures. In some soils, however, owing to their capillarity, even though the ground-water level be several feet below the pavement, the material still remains in a condition that makes it unfit for and incapable of carrying the loads imposed upon it. The Federal Government has done some very interesting research work in which it is shown that, by the admixture of Portland cement or lime, not only is the change of volume of such soil between the dry and the wet states materially reduced, but the soil is rendered much more stable. The research work has also shown that, by interposing a layer of pervious material, such as sand or cinders, between the subbase and the bottom of the pavement, conditions are improved for the reason that the load is spread over a greater area and the unit pressure is reduced.

To secure a hard, smooth and durable pavement, it is necessary to place upon the subgrade a structure sufficiently rigid to transmit and distribute the load placed upon it and, having a surface that meets the above requirements, to carry the traffic. Until comparatively recent years, this has been accomplished by placing stone on the prepared subgrade, usually beginning with the larger sizes, filling the voids with smaller-size stone, compacting the whole mass by rolling, or otherwise, and placing on this foundation either a finishing-coat of fine stone and screenings or a bituminous mixture of some kind.

Such surfaces are still used and probably will continue to be used on many roads where the traffic is light and when funds are not available for a more permanent type of construction, but in the design of highways that must accommodate the heavy-truck traffic of today it seems that only a base of rigid material of sufficient thickness to carry any loads that may reasonably be placed upon them should have consideration; and the only material that practically meets this condition is a concrete mixture.

The Concrete Base

Much valuable research work has been done in determining the characteristics most desirable in the base of such a pavement. The statement that concrete forms a rigid base is only comparative, for it must be realized that concrete possesses some elasticity and is subject to the same distribution of stresses that applies to any other

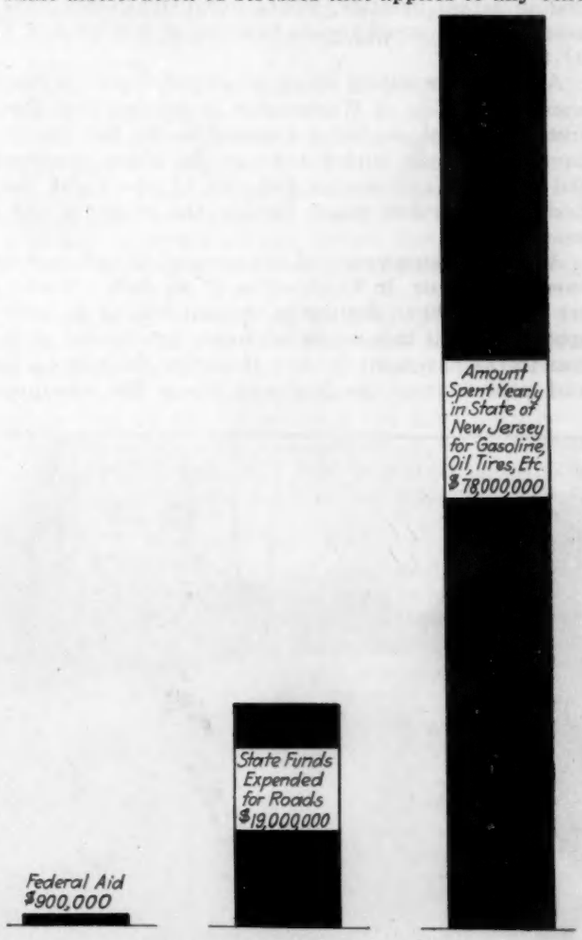
Amount Spent Yearly in State of New Jersey for Gasoline, Oil, Tires, Etc $78,000,000
State Funds Expended for Roads $19,000,000
Federal Aid $900,000

Fig. 10—Comparison of the Money Spent by the Residents of the State of New Jersey for Gasoline, Tires and Oil and Road Improvement and the Amount of Money Received by the State under the Federal Road-Aid Act

The Amount Spent for the Necessities To Run the Vehicles Is Approximately Four Times the Sum Expended for the Roads on Which They Are Run and the Amount Paid for the Vehicles Is Approximately $440,000,000

FIG. 11—A TYPICAL NEW JERSEY CONCRETE ROAD
Note the Longitudinal Joint Through the Center. By This Method the Strength of the Road Is Increased Four Times, Considering the Pavement Transversely as a Beam

elastic body, and that moving loads passing over the pavement and changes in the temperature and the degree of moisture produce stresses that must be carefully considered and provided for. For this reason, in laying a concrete pavement it is necessary to construct expansion-joints at frequent intervals; otherwise the pavement will crack because of temperature changes. Judging from tests made by the Federal Government and in actual practice, where expansion-joints have not been provided, cracks seem to occur at intervals of about 60 ft.

Another interesting thing developed from the research work in the City of Washington is the fact that the concrete pavement, on being exposed to the hot sun in the daytime, actually curled down at the edges, compressing the subbase; and during the cool of the night the opposite effect takes place, leaving the edges of the slab unsupported.

Actual measurements of the amount of this movement have been made, in hundredths of an inch. Those who are accustomed to dealing in thousandths of an inch will appreciate that this condition forms an element of weakness in the pavement in that, if during the night a heavy load passed over the highway along the unsupported edge, the corner formed by the edge of the pavement at the expansion-joint might be broken off; and this, in a number of road-tests that have been made, is exactly what has happened. The result of the failure of the corner is the forming of a depression in the pavement; a loaded wheel, therefore, passing over this depression, ruptures by impact the concrete immediately adjoining the depression, and the destruction of the pavement from that time on is very rapid. In some of the States, this has led to the adoption of a design of pavement in which the concrete at the edge is made thicker than at the center of the road.

FIG. 12—GRANITE-BLOCK PAVEMENT LAID UNDER THE SUPERVISION OF THE NEW JERSEY STATE HIGHWAY DEPARTMENT
While Concrete Is Probably the Most Economical Type of Surface for General Use, Where the Traffic Is Very Heavy and Consists Largely of Motor Trucks, Considerations of Economy Call for the Installation of a Granite-Block Wearing Surface

Possibly because of this movement at the edge of the pavement and because of the loads passing over it, but more probably because of the fact that in improving the highways an old road very often is widened out and the subgrade is better compacted at the center than at the edges, it has been observed that, when concrete pavement has been laid for the full width, a longitudinal crack generally forms. Our experience in New Jersey therefore has justified us in constructing pavements with a longitudinal joint through the center (see Fig. 11). Considering the pavement transversely as a beam, it will be noted that by this procedure we have increased its strength four times, but, on the other hand, we have introduced twice the number of corners, which are potential points of failure, provided the pavement is not sufficiently thick to carry the loads safely. To follow out the theory of making the pavement thicker at the edges would in this case necessitate its being made thicker in the middle. The difficulty of preparing a subgrade to provide for these conditions is so great, however, that I believe it to be just as economical to put in a uniform thickness of concrete, the cost of any slight excess of concrete over what might be theoretically required being offset by the simplification of the work on the subgrade.

The stresses in a concrete pavement caused by the loads passing over it are, as I have said before, impossible to analyze, owing to the fact that subgrade conditions are not determinate, and the additional fact that, although the maximum load permissible is limited by law, undoubtedly many violations occur. In arriving at the thickness of concrete pavement, therefore, it is necessary to make assumptions as regards subgrade and load conditions that seem to be safe, and to design the pavement on the basis that the maximum fiber-stress shall not exceed 50 per cent of the ultimate tensile-strength of the concrete, for research work has developed the fact that although concrete, like iron and steel, is subject to fatigue and failure, it may be stressed an indefinite number of times, provided the maximum stress does not exceed 50 per cent of its ultimate tensile-strength.

In the preparation of subgrade and the construction of the actual base of the pavement, the work being done at this time is tending toward a design that, with respect to these two particular items, can be regarded as providing a permanent pavement and, with the application of a suitable wearing surface, a pavement properly fulfilling the conditions required by the traffic of today.

BEST WEARING SURFACES

The wearing surfaces in use at the present time that are deserving of consideration are a bituminous mixture, concrete, and granite block. The first-named has been in use for many years and has given satisfactory service, but under the heavy traffic of today would, I believe, not be an economical form of surface to use; it has the

further objection of being very slippery in wet weather. The concrete surface must be constructed monolithically with the base and is therefore not renewable; but under reasonable traffic conditions it should be good for from 15 to 20 years; except under the heaviest traffic conditions, it is probably the most economical type of surface for general use. In the case, however, of a highway on which the traffic is very heavy and consists largely of motor trucks and certainly in the case of a motor-truck trunk-highway it would be the part of economy to install a granite-block wearing-surface of the type shown in Fig. 12.

I am of the opinion that the potential capacity of highways is greater than we are willing to admit. The capacity of most mediums of transportation has been underestimated, as, for example that of the New York subways, the Hudson & Manhattan tubes and even the railroads of the Country, all of which are carrying a much greater volume of traffic than was considered possible at the time they were projected. This has been due to better regulation of traffic and to improvement in the vehicles themselves as regards their ability to operate under conditions of congestion. I feel certain that the same improvements, if applied to highway traffic, would largely increase the capacity of the highways.

While giving careful study to the proper design and construction of highways as regards their durability, we are not losing sight of the principles of economics that present themselves in connection with the operation of the highways. I do not know that figures have been prepared showing the estimated cost of operating the motor vehicles of this Country, but I believe that a conservative figure for the two essential items of gasoline and tires alone would probably be not less than $2,500,000,000, certainly a sum sufficiently large to justify efforts to make improvements that will tend toward saving in operating cost. Improving the character of the paved surface produces a marked effect in this direction, the fuel consumption having been demonstrated by actual test to be approximately 25 per cent less for a motor vehicle when traveling over a concrete surface as compared with an unimproved road; and I am of the opinion that the percentage of saving, as regards wear and tear on the vehicle and the tires, would be as much as, if not more than, this.

Adjustment of Gradients

Another important consideration is the adjustment of gradients along economic lines. This subject has been investigated at the Iowa Engineering Experiment Station, the results seeming to indicate that descending traffic requires considerably lower gradients for economic operation than does ascending traffic, and that the maximum economic grades are practically as given in Table 1.

TABLE 1—MAXIMUM ECONOMIC HIGHWAY-GRADES

Distance, ft.	Ascending Traffic		Descending Traffic	
	Commercial Cars	Automobiles	Commercial Cars	Automobiles
300	10.0	...	7.0	12.0
500	7.5	13.0	5.0	10.0
1,000	6.0	10.0	3.5	5.5
2,000	5.3	8.5	2.8	4.2
3,000	5.0	8.0	2.6	3.3
7,000	4.8	7.3	...	...

In connection with the proper adjustment of gradients, the question of the reduction of the total rise and fall should be considered. The capitalized value of the saving procurable is shown in Table 2, which was prepared by O. L. Kipp.[2]

TABLE 2—CAPITALIZED VALUE OF SAVING 1 FT. OF RISE AND FALL WITHOUT INCREASING THE DISTANCE[1]

Vehicles per Day	Yearly Saving			Annual Saving Capitalized at 5 Per Cent Per Year		
	Grades, Per Cent			Grades, Per Cent		
	2	5	10	2	5	10
100	$2.40	$9.50	$19.00	$47.50	$190.00	$380.00
1,000	24.00	95.00	190.00	475.00	1,900.00	3,800.00
10,000	240.00	950.00	1,900.00	4,750.00	19,000.00	38,000.00

[1] Based on a car-mile operating cost of 10 cents per mile and the operation of the vehicles for 250 days per year.

In an earlier part of this paper, in speaking of the proposed highway leading from the vehicular tunnel, I stated that the saving of 20 ft. in rise and fall, accomplished by constructing the section of the highway through Jersey City in an open cut below the level of the streets, would effect a saving in operation which, when capitalized, would more than pay for the cost of the work. The gradient of the approach to this subway is approximately 3.5 per cent and the estimated volume of traffic is 67,000 cars per day. Applying Table 2 to these conditions and interpolating, as between the 2 and the 5-per cent grades shown therein, it is seen that the annual saving in operation would amount to $79,930, which, capitalized at 5 per cent, would give an amount in excess of $1,500,000, which exceeds the cost of making the improvement.

Any shortening of the distance to be traveled, particularly where the volume of traffic is heavy, also forms an important consideration in reducing operating expense, as does also the elimination of the grade-crossings of railroads and other points of danger and delay. I am convinced that, by employing the principles of economics in highway construction and design, the cost of operating motor vehicles can be reduced approximately 50 per cent.

In conclusion, I would say that in this paper I have endeavored to place before you some of the problems that confront us in our effort to improve the highways of the State of New Jersey, and to indicate some of the methods that we are following in our effort to solve the problems, together with a suggestion of the unfortunate results that will follow if this important work is not made to keep pace with the demands upon it.

DISCUSSION

Dr. W. K. Hatt:—The only question I could raise regarding Major Sloan's paper is as to the cost of granite-block surface as reflected in the operating expense and the depreciation of the vehicles. This might entirely overbalance the extra wear on a smoother surface.

S. P. Thacher:—I have been very much interested in Major Sloan's paper, first, because my work keeps me in touch with many of the problems that confront him and, secondly, because I am a resident of the very district he describes as being menaced by decreasing property values because of motor-traffic congestion. My home is in Freehold, N. J., through which pass the main traffic routes from Trenton to the coast and from Camden via Lakewood to Jersey City. The first of these follows streets that were laid out many years ago and has one right-angle turn and several jogs. On Sundays in the touring season these streets are clogged with traffic. This condition could be avoided easily by a simple straightening of the highway.

[2] See *Engineering News-Record*, April 19, 1923, p. 699.

The subject of pavement life is, of course, bound up very closely with resistance to vehicle impact, and we tire engineers must do our share in making the latter factor more reasonable. Tires that cushion the vehicle also cushion the road. We are continually improving the cushioning qualities of tires and are thereby increasing the life of the vehicle and of the pavement. This will, in the natural course of events, lead to greater traffic congestion unless the present highways are straightened and more highways are constructed.

M. W. WEIR[4]:—The public should be educated to understand that, because of the delays due to traffic congestion that is due to preventable cause, an excessive tax is being paid for inadequate streets and highways. It is manifest that any machinery, whether it be a mill or the machinery of traffic, is efficient and economical only when it can be operated continuously and without slowing-up. The importance of eliminating the grade-crossings of railroads and unduly congested traffic cannot be overstressed. It is common to cite 42nd Street and Fifth Avenue as the ultimate of congestion, but there are places outside of New York City where grade-crossings of main highways are congested beyond anything that could be tolerated at 42nd Street and Fifth Avenue. I have experienced a wait at such a crossing that consumed 35 min., notwithstanding traffic control and police.

When a fine wide highway is built and put into use, maintenance must begin at once so that the maximum efficiency can be maintained continuously. Congestion and consequent delays in motor traffic mean greater expense of transportation in exact proportion to the loss of earning power of a motor vehicle. This is illustrated in the short-hauling of freight from place to place by motor truck, the price being calculated not on mileage but on the time consumed in passing through congested districts and to docks and freight-yards where delays are inevitable.

Major Sloan's calculation of the number of motor vehicles per capita in the United States does not convey a full conception of the congestion of large centers where automobiles from miles of country around concentrate on special occasions, and trucks concentrate every work day.

Relief from the rapidly increasing congestion of our main highways must be accomplished; otherwise the automobile industry, as well as others, will experience adverse effects, for the feeling is increasing among many drivers, particularly those who are nervous, that it is no longer feasible to take a car out on Saturdays, Sundays or holidays, because of the danger and the inability to move with sufficient expedition to reach an objective and return in time to get the prescribed 8 hr. in the arms of Morpheus. The streets and highways of our cities and their environs are rapidly reaching a condition comparable to that of the subway systems within the city. That is to say, the streets and the subways are reaching the ultimate limits of their capacities. And, still more alarming, the city itself is close to the limit of its capacity to contain streets and subways. In New York City, paradoxically, increased traffic facilities have increased congestion. The same thing is more or less true of all centers of activity.

In the construction of cities and centers of industry and business we seem to have neglected to calculate the capacity of the foundation upon which we have built, with respect to the street and highway system. When we build a new building we construct a foundation that is calculated to carry the load and if, after the building has been finished, we wish to add several stories to the height, we must first satisfy the building department that the foundation will carry the extra load, which is a safe and sane thing to do. But, on the original city foundation of streets, built to carry a load comparable with a two-story frame building, we go recklessly on and on adding load upon load of steel, brick, stone and concrete, story upon story, and thousands upon thousands of persons, blithely forgetting the foundation until the structure begins to sag and crack. Then we suddenly wake up and try to bolster and underpin the crumbling base with street widenings and subway lines. The solutions of the problems of traffic congestion so far applied have served to allay the pain temporarily, only to be followed by an aggravated case of the same disease.

Why shall we not strike at the cause of the trouble and stop excessive centralization and excessive superstructures on streets and highways originally designed to carry light loads? Is not the State neglecting its plain duty when it does not employ a definite system of developing its industrial resources by making accessible places of geographic advantage, other than those points already centralized?

The manner pursued from the time of the pioneers was to let the center come into being before a good road was constructed, thereby permitting the center to control the road whether that was to the benefit of the State or not. If the road is built in advance of the centralization, the degree of centralization can be largely controlled by constantly opening new centers. Under the present system we pyramid expense upon expense in the effort to ameliorate traffic conditions, only to find the remedy is pyramiding the trouble as we struggle to apply the wrong solution.

It is not meant that these comments should convey the impression that streets and highways within and to existing centers should not have every improvement possible, but only point out the danger, which is imminent, of excessive centralization.

A suggested solution is that railroad companies, together with truck companies, as one corporation or as separate corporations, guided by this Society and other societies, establish at convenient points, removed from present congestion, where future congestion can largely be avoided, yards where the railroads can break bulk and the goods be distributed to their destinations by motor trucks. This would create new centers from which new routes could be laid out. It is suggested that, where new routes are laid out, or traffic is routed over existing streets or roads, the routes for passengers be segregated from those for freight traffic, that passenger-traffic routes be laid out through the business and the residential zones, and that all freight routes, so far as possible, be laid out through industrial zones.

Automotive engineers interested in highways should do all they can to encourage through-routes in scenic country, making the highways attractive in appearance by having trees planted and keeping them as pleasure routes away from the trucking routes.

Parallel highways for relieving existing traffic congestion in both suburban and urban districts should be laid out with the thought always in mind that they are for the best interest of the State and its political subdivisions; it is far more economical to create new ratables than to tear down and destroy old ones. Therefore, when new routes are proposed, they should be carefully located and placed away from the built-up districts, thus insuring that the minimum destruction of ratables would occur.

[4] Charles W. Leavitt, New York City.

MAJOR W. A. WELCH[5]:—The State of New Jersey, as well as everybody who is interested in public roads throughout the Country, is to be congratulated upon the present Highway Commission of New Jersey, a body of men who have had the courage, the foresight and the vision deliberately to lay out a system of real highways in the State and to disregard all local and political influences intended to prevent their going the way they wanted to go; it seems to me that the engineer they have secured is the right man to carry out these projects. I have had the pleasure, during the last year, of making a careful examination of a piece of highway that they were building with prison labor. They had to go round all sorts of corners and invent all sorts of reasons to get this prison labor to work on that highway, but they did it and built the best piece of concrete road that I know of in the United States. They have made a careful study of traffic conditions in New Jersey; they have devoted a great deal of time to it and have worked out, as well as any body of men could, the solutions of some difficult problems in this metropolitan area.

But theirs have not been the only problems in this metropolitan area. The Superintendent of Public Works of New York State has also had some problems to contend with. I know of some of the plans that he has worked out to relieve congestion, because we all have a new problem. First, we had canals; then we had railroads and trolleys. The day of the trolley has gone and the day of the railroad, for anything but through-hauls, has gone. We must depend on the motor vehicle and on the highway to carry it. Naturally, we should expect that the old engineers who built the railroads and went through 40 or 50 years of evolutionary construction would be the ones to lend their brains and their experience to the construction of highways. But, unfortunately, in many instances that has not been the case. It is not the fault of the engineers; it is not the fault of the automobile men. It is the fault of the lawmakers. New York State cannot build a bridge more than 5 ft. long without a special act of the legislature; New York State cannot buy right-of-way; the county and the town must do that. The result is that the highways run around corners because local authorities will not condemn a piece of property that costs $500; they make the persons who use the highways burn $5,000 worth of tires going around the corner. This sort of thing is being done all over the United States, because the laws governing motor-vehicle transportation have not been brought uptodate.

Our common law says that the highway belongs to the people; that they have all rights on it. But it does not give to anybody the right to use the highway in a money-making venture. We made the railroads buy their rights-of-way and pay taxes on them; we make the trolleys buy theirs and pay taxes on them. We have made them public service corporations. What are we to do with the persons who operate motorbus and freight lines over the highways? It is the lawmakers who are behind in all this; they are worse than the engineers! The engineers are learning how to build roads. They are learning that there is no difference, economically, between a highway and a railroad. The roadway itself is the same in both instances. If a railroad company intends to run fast trains and carry heavy loads over the road, it will put 130-lb. steel over it and ballast the top of it, but the roadway is the same as if they rolled on 80-lb. steel over it. The road engineer must learn that his road-bed must be just as good as the railroad road-bed.

On two things I cannot altogether agree with Major Sloan. I cannot see the necessity for an 80-ft. highway nor for a 50-ft. highway. The railroads build four, six and eight-track roads. I do not believe in mixing traffic, one kind against the other, on one highway; I think we shall come to realize that we shall have to separate it. We can put slow-moving traffic on one side of a road for local runs and put express on the other side, but we must not have anything coming against them. Also, I cannot see why a perfectly smooth surface is not the most economical highway surface. I do not believe that granite blocks can be made perfectly smooth. I do not believe that they will outwear good concrete.

A. J. SCAIFE:—Major Welch and Major Sloan referred to the railroads' methods of handling freight between small stations. We know, of course, that the Pennsylvania Railroad Co. at the present time is going into that question extensively. It costs a great deal to have a local train cross and recross the main tracks in distributing less-than-carload freight. It is also dangerous. Under the system of loading cars for stations along the route certain numbers of miles, 60 to 65 or 70 to 100, going up one side and coming down the other side, the train being met at the stations by one, two or three trucks, according to the amount of freight, and the freight being distributed from those stations, we can see readily that it takes only a short time to deliver the freight to the door of the customer, obviating the necessity of carrying it from a central freight-station to a local freight-station as is being done at the present time.

More and more of the local-freight traffic will be handled over the highways, especially those paralleling the railroads; this certainly will mean considerable new engineering thought on highway construction.

PRESIDENT H. M. CRANE:—I doubt whether we all realize what a wonderful story Major Sloan has been telling us. I have been a member of the Advisory Board on Highway Research for several years. It is doing a very valuable work. We have had reports on highway finance, sub-grades, material, construction, and all the phases of highway engineering except the great question of the through-highway. That has never been mentioned at any of the meetings. I have been asking about it from time to time and have been hoping that some day we should have just what Major Sloan is preparing to give us in New Jersey.

I took out my first driver's license in New Jersey. I have done a great deal of driving in New Jersey. I still find it very difficult to find my way from the Hudson County Boulevard to any one of the three or four ferries to New York City, although I have been over the route many times. In fact, when I drive through Jersey City it always reminds me of a nickel-in-the-slot machine, in which the nickel goes bouncing down from one peg to another.

Conditions were not so bad in the old days, because there was not much through-traffic, only a few car-lines. Today it is a serious matter, and Major Sloan has told you what is being done about it; his is a real solution, not merely a half-hearted widening of a few streets.

We have the same problem in New York City and I wish someone would give us the same cheering story regarding it. Colonel Greene tells me that he lives at Port Washington; he knows about what they are now calling the Northern Boulevard, which used to be Jackson Avenue and Broadway, Flushing, and about the bridge over the meadows at Bayside, which, because of

[5] Chief engineer and general manager, Commissioners of Palisades Interstate Park, Iona Island, N. Y.

the ramps approaching the little man-power lift-bridge, reduces traffic speed to 10 m.p.h. or less, and two lines of cars going in opposite directions can barely pass. This is the main highway out of New York City to the northern shore of Long Island. The condition is obviously a bottle-neck on that highway, absolutely fixing the speed of traffic there at any congested period.

I think Major Sloan's proposal to abolish certain grade-crossings, even highway grade-crossings, is a wonderful idea. If the Hudson County Boulevard were crossed at grade, the efficiency of operation would be cut nearly in half.

I should like to call attention to the fact that I think this meeting is the occasion of the first announcement of the policy of really building roads from one place to another, instead of improving local sections of highways. I am sure you will agree with me that it is of the greatest importance and the most cheering message we have had in a long time.

C. O. BECH[6]:—The hauling we do is only over short distances. We have stations scattered all over the country; the radius of the hauls from these stations is probably 10 to 15 miles at the maximum. There is a possibility of our going into the subject of carrying our product on trucks and trailers, instead of turning this business over to the railroad company for short hauls from one station to another; but up to the present time we have not had sufficient experience to make a statement.

COL. F. S. GREENE[7]:—Wherever one goes, one will hear persons damning the truck, saying that it is breaking up the roads and ought to be taxed out of existence. While I regret that the truck breaks up the roads, I do not condemn it or blame it for doing so. What I blame is the short-sighted engineers and the short-sighted legislators who do not give us enough money to make a road that will carry a truck.

My idea of building roads is that they should be constructed so that they will carry the legal weight 365 days of the year, and not fail like tissue paper. I am glad to see, from what we are to have in New Jersey, that the road will cost $1,000,000 per mile. If the road does not endure, heaven only knows what we shall arrive at!

A large question, to my mind, is whether the Country is yet ripe for a truck road, pure and simple. I am inclined to believe that we should have a combination road that will carry trucks on certain parts and passenger automobiles on other parts.

We are now designing what will be known as the Pipe-Line Boulevard, which will run from some point in Brooklyn across Nassau County; I will submit this to your attention, to see what you think of the design. I am laying out the pavements 36½ ft. wide. We are providing four traffic lines of 9 ft. each; the two outer traffic-lines are designed for trucks, and will be of concrete, 9 in. thick, heavily reinforced; they will be separated from the two inner traffic-lines by a 2-in. bituminous joint. The two lines of traffic for passenger automobiles will be 7 in. thick, heavily reinforced. If I were building that road on a clay foundation, or a foundation of which I had some doubt, it would be made thicker. On Long Island we have a sand foundation.

Regarding the question of traffic lines, I should like to ask, Why build a road 50 ft. wide? The minimum width of road that should be built to carry one-way traffic is 8 ft.; that is uncomfortable and dangerous; the moderately comfortable width is 9 ft. I presume that in New Jersey and in practically every State, the body of any automobile or the load that any automobile may carry is limited to 8 ft. in width; so, with the overhang, on an 18-ft. road you will have plenty of space for two 8-ft. trucks to pass one another. I would, however, build a two-way road near cities even wider, especially if I thought it would be traveled by many 8-ft. trucks. I suppose that not 1 truck out of 100 is 8 ft. wide; 7 ft., or even 6½ ft. makes a very wide truck.

In Westchester County, where we have large trucks and many of them, we use the 10-ft. unit, building a two-way road 20 ft. wide and a three-way road 30 ft. wide. The inner 10 ft., of course, is used only when one car is overtaking another, or on special occasions when three cars might meet.

So, when I hear that a road 50 ft. wide is to be built, I am somewhat puzzled. That means five-way traffic, and I am wondering whether four lines would not be better, in view of the large saving that would be secured.

The only real criticism that I would make of Major Sloan's very excellent paper is regarding the use of granite blocks. I must confess that I do not agree with him at all as to this. If we had steel tires, I would agree fully with Major Sloan, but today steel tires are very scarce and are used only on short hauls. The farmer is about the only person who uses a steel tire outside the city limits, and he uses it only in going from the barn to the field.

Our experience in New York is that the wear on a concrete road, built of proper sand and proper stone (cement is practically standard now) and with the proper mix, is so small that it can hardly be measured. We have roads 10 years old that carry heavy traffic. Remember that for the first 5 years of their lives they carried more steel tires than they carry now. But the broom-marks left in finishing the roads are still there. One road, a main-line road from Buffalo to Rochester, is a little more than 10 years old. Right in the main lines of travel, that road has worn down probably ⅛ in. in 10 years; but on the major portion of the pavement the broom-marks can still be seen. I think that tire men will agree that even on large trucks the pneumatic tire is coming in more and more.

MR. BECH:—On trucks of over 2-ton capacity cushion tires are used chiefly, that is, solid tires having a cup-cushion or some other cushioning device.

COLONEL GREENE:—That is not a tire that would wear down a good concrete road to an appreciable extent. If the problem is figured out carefully and the little roughness that is bound to occur is taken into consideration, no matter how well Belgian blocks may be laid, the concrete road is bound to come. If you figure, say, that at the end of 20 years the pavement will be worn-down 1 in., another 6-in. top of new reinforced concrete could be put on more economically than new Belgian block could be laid. As I understand it, Belgian block is now more expensive than any concrete. Experiments in our laboratory show that the wear of a Belgian block and that of a good block of concrete mixed 1 to 1½ to 3 are very nearly equal, the actual difference in wear being much less than the difference in price.

Mr. Crane said that he believed that this is probably the first public meeting at which the idea of taking practically a direct line for heavy traffic from one crowded center to another has been brought out. I think he is

[6] M.S.A.E.—Superintendent of motor equipment transportation, Texas Co., New York City.

[7] Superintendent, Department of Public Works of the State of New York, Albany, N. Y.

right, but for your information I will say that I have now before the legislature the fourth highway map that I have presented. The other three were scrapped, and this will be scrapped, I think. On that map I laid out a line from Buffalo straight through the country to Albany. I stated that if that road were ever built, if the legislature would adopt it in the State system, it would be the shortest road across the State. I showed exactly how many miles it would save and stated that I believed it would be the most heavily traveled truck-road in the State. Aside from its being scrapped by the legislature, which I expected for purely partisan reasons, I found that the far-sighted and brilliant editors of Rochester, Syracuse and Utica all condemned that road. They did not have vision enough to see that the most expensive thing they could have is a line of heavy trucks going through their city streets, jamming up traffic and breaking up the streets, and the drivers hardly spending a dollar. They could not appreciate that the tourist, who has money to spend, driving along this road just to the south of those cities, would, when nightfall came, go a few miles north to get to a good hotel or see a good theater, and that the additional tourists this road would create would more than make up for any slight loss there might be from the fact that truck drivers did not go into the city.

F. C. HORNER[8]:—Probably you are all well acquainted with the activities of the Chamber of Commerce of the United States of America in appointing six committees to make a study covering all forms of transportation throughout the Country. The committee in which we are particularly interested is the one that dealt with the relation of the motor vehicle to other transportation agencies, the purpose being, if possible, to establish a plan for the proper coordination of the various transportation facilities, with particular reference to the place of the motor vehicle.

Properly coordinated transportation facilities are absolutely essential to the efficient and economical transportation of both passengers and goods. According to the recommendations of this report, which many of you probably have seen, ruinous competition and waste effort in transportation operations must stop.

To accomplish this will require the very best efforts of everyone concerned; the transportation companies, the merchants and the public which, of course, includes the legislative bodies, both National and State. To fit the new transportation facility, the motor vehicle, into its proper niche, it will be necessary to have legislation, perhaps not very much but enough to give the major transportation facilities the opportunity and the privilege of using the motor vehicle to meet their particular requirements.

Please do not jump to the conclusion that the recommendations of Committee Four, the Committee I am speaking of, advocated that the railroads, the waterways or the steamship interests should own and operate motor vehicles. That is left to be decided through the process of evolution. At the moment, I do not believe that the railroads or the steamships, but especially the railroads, intend to purchase and operate motor vehicles of their own. The probability is that, for the time being at least, they will use existing transportation organizations and equipment for their purposes; in other words, they intend to crawl before they walk, and walk before they run, which is a very wise policy. Later on the railroads may own and operate fleets of motor vehicles, but that is in the future so far as I can see, and also I believe so far as the members of the Committee that made the recommendations to which we are referring see.

The railroads are handling traffic now that is decidedly unprofitable for them to handle. Far-seeing railroad executives, or you might say practically all of the railroad executives, concede this point, but they have only come to see it within recent years, more especially within the last year; you may say that opinion on this subject has crystallized materially since the recommendations of Committee Four were made. Certainly, motor-vehicle haulage, as an adjunct to railroad transportation, has been started by the Pennsylvania and the New York Central railroads very recently and further developed since the report appeared. I think that it is rather significant to note that fact.

On the other hand, the motor vehicle is certainly attempting to handle traffic beyond its economic limitations. Given organized collection and delivery at the point where the rail-line haul ends, other things being equal, it is cheaper to transport goods and passengers by rail than by highway. On the other hand, within the economic limitations of the motor vehicle, it is more economical to transport by road.

The point is, we must fit each one of these facilities into its proper place. The railroads must give up certain classes of traffic that are unprofitable to them now. A case in point would be the shipping of local less-than-carload freight from New York City, we will say, to Paterson, Newark and points adjacent to the metropolitan area of New York City. Not only the cost of handling less-than-carload freight by rail, but also the additional cost of handling through main-line traffic that is interfered with in the yards of the railroads must be considered, in weighing the advantages and disadvantages of hauling by rail such classes of traffic to such points and within such radii of activity, as compared with the cost of handling it by motor vehicle.

Therefore, it is to the best interests of us all, and especially those connected with the automotive industry, to make every effort to find the proper place of the motor vehicle and to assist the railroads and the other transportation agencies in applying it to their requirements. The motor vehicle is the necessary adjunct for coordinating all transportation facilities; in other words, in handling the short-haul movement in the terminal areas and in railroad cartage-service for delivering and picking up at the store-door.

WALTER KIDDE[9]:—This last report was particularly interesting to me because it brings out a point that has been omitted in the discussion tonight, that is, the ultimate great value of the motor-truck trunk-highway talked about as a means of distributing less-than-carload freight to and from a distributing-station to be located somewhere in the Hackensack meadows.

I want you to visualize what it would mean to New Jersey and to New York City to have freight broken up in a station in the Hackensack meadows, brought in by motor trucks direct to New York City, and delivered to the merchant's warehouse; similarly, delivered in Newark and Paterson and to all of that industrial section of New Jersey. That particular phase of the subject has not been emphasized in presenting road problems to the people of New Jersey, but we have been studying the matter in conjunction with the port authorities, and I should like to assure you that that is not one of the least of the many points that caused the State Highway Com-

[8] M.S.A.E.—Manager, railroad transport engineering service department, General Motors Corporation, New York City.

[9] Member of the New Jersey State Highway Commission and consulting engineer, New York City.

mission to recommend this very expensive and rather far-seeing project.

In England the railroads now take care of freight in just the way that has been indicated by Mr. Horner. The time is coming when freight will be taken by motor cars from the factory to distributing points, loaded on trains for long hauls, then broken up in the West, or wherever it may be, and delivered at destination to the door of the factory by motor truck. That is the ultimate end and the coordinating function of the highway for which we are planning today. It must coordinate with the railroad to be effective; and in my opinion an interesting and far-seeing investigation will be made to determine just how far State authorities may go.

To develop thoroughly the value of such planning I want you to think of the resources and business affected thereby. Picture the State of New Jersey, we will say, in an effort to make a tabulation of its complete assets, such as a going concern would tabulate. Figure out if you please the traffic and passenger operations of the State; how much these operations cost. What is the investment of the general public in vehicles? And just what relation does this investment bear to all the manufacturing industries and the other great functions of the State. Then study how the capital account allotted for the building of roads is at present related to the expense account of all these functions and the great values in the State that lie undeveloped.

I want you to think of what it would mean to take care of the State of New Jersey thoroughly, considering all the people in one great corporation investing time and money to best effect. When you think of the wonderful country in the north, the hills where people may go for recreation, the great seashore playground on the Atlantic Coast, the possibilities of industry along the main railroad-lines from Jersey City through to Camden and of the new canal that is to be built between two of the greatest cities in the world, which will develop business for the State of New Jersey in a very wonderful way, you visualize what a far-sighted Highway Commission could do in preparing the way for the State to enjoy to the full prosperity which should be hers by reason of all her natural advantages.

In closing, I want to tell you that it has been a pleasure for me to take the plans of the gateway projects, as they were worked out by Major Sloan, and present them to Mr. MacDonald, chief of the Bureau of Public Works at the City of Washington, for the purpose of securing possible Federal-aid. It was very gratifying to me to have Mr. MacDonald say that the plans, the specifications and the projects that were laid before him, those described here tonight, were of the most advanced character for that kind of work that he had ever seen. He therefore adds his testimony to the value of Major Sloan's work just as you all have too.

MAJOR W. G. SLOAN:—One point that both Colonel Greene and Major Welch, as well as Dr. Hatt, commented upon in connection with the paper is the matter of granite-block paving. I admit that there may be a question regarding that. However, certain conditions exist in our State under which we find that it is the only thing to use. I have in mind particularly heavy grades. When we have an excessive grade, we find that it is the only thing that we can use with safety, and it is certainly the only thing in the way of a replaceable surface, thus affording a permanent pavement that can be used under the heavy traffic, that we shall probably get.

As Commissioner Kidde has said, we are looking at least 25 years into the future. Truck traffic has developed along lines that approach the maximum limit as to both weight and size. We have figured that it is safe to assume that we should allow a 10-ft. width for each traffic-line. To carry such traffic as we believe we shall have to carry, that is, 5500 vehicles per hr., four lines moving rapidly and almost continuously will be required. We figured that such traffic could be kept moving under all contingencies. It is possible, or probable, that a truck will either stop to deliver goods or break-down, or that something of the sort will happen, disorganizing the four lines of traffic if an additional line were not provided. That was the reason for adopting the 50-ft. width.

THE MOTORSHIP

ALTHOUGH the history of the motorship commenced with the Selandia in 1912, it was undoubtedly true that much and valuable experience had been obtained with Diesel engines on smaller ships prior to that date. Since 1912 progress had been steady, although interrupted by the war, and the following figures show the state at July 1 of the different years mentioned.

Date	Number of Motorships in Service	Tonnage
1914	297	234,287
1919	912	752,606
1920	1,178	955,810
1921	1,473	1,248,800
1922	1,620	1,542,160
1923	1,831	1,668,414

Of ships under construction the motorship tonnage was 10.9 per cent of the steamship tonnage at December, 1922, 12.0 per cent at March, 1923, 18.0 per cent at June, 1923, 24.0 per cent at September, 1923, and 35.5 per cent at December, 1923. A large number had since been ordered, but were not included in the figures of the table, as they had not been commenced. They included 10 motor passenger liners of 158,000 tons gross, the largest being of 22,000 tons gross and having twin machinery of 20,000 i. hp. The fuel consumption is 20 to 25 per cent by weight of that of a corresponding coal-fired steamer, and between 35 and 45 per cent of that of an oil-fired steamer. For equal dimensions and speed the motorship has a higher deadweight capacity of from 5 to 15 per cent. A smaller engine-room staff is carried on the motorship, but the average pay is, however, higher, and the financial saving is usually not more than 5 per cent. Disadvantages of the motorship are the relatively high capital cost, the greater consumption of lubricating oil and the limited supply of motorship engineers available.

Comparing two 10,000-ton ships in service, the motorship fuel cost was shown to be 46 per cent of that of an oil-fired steamer, and, considering exactly similar vessels of 450-ft. length running at 12 knots and having Diesel engines, coal firing and steam engines, and oil firing and steam engines, the daily fuel-consumption was given as 17, 70 and 40 tons respectively. Typical cargo ships gave the following figures:

Deadweight, Tons	Speed, Knots	Daily Fuel-Consumption, Tons
14,000	12.5	21.0
12,350	11.3	16.0
10,000	10.6	10.0
9,300	11.1	11.4
7,500	10.5	9.0

—From a paper by A. P. Chalkley, presented at the First World Power Conference.

Motorbus Transportation

By A. E. HUTT[1]

PENNSYLVANIA SECTION PAPER

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

THE discussion of this paper, as printed herewith, is that presented at the Pennsylvania Section Meeting held on May 13, 1924, after the delivery of the paper; it includes written contributions by members and remarks made at the meeting. An abstract of the paper, as then delivered, precedes the text. A reference is given to the issue of THE JOURNAL in which the paper was printed, so that members who desire to refer to the complete text as originally printed can do so with a minimum of effort.

ABSTRACT

THE underlying principles of motorbus transportation are outlined and suggestions are made concerning certain features that are conducive to successful operation. Among the points that should have careful consideration are said to be correct design and construction, efficient maintenance, intelligent operation, courteous employes and protective franchises. Special attention should be given to the design of parts, such as clutches, brakes, body details, including seats, and the protection of passengers against wind, rain and sun. Modern motorbuses are arranged for use with the P-A-Y-E system and when operated by one man a front-door exit is important.

Statements regarding the cost of maintenance are misleading because this depends upon the locality and the type of equipment. A low cost of fuel may be offset by a high cost of platform-men because of a lower speed of the motorbus. The total cost of operation is the important factor, not the reduction of any one item at the expense of another.

Maintenance also comprises both general overhaul every 2000 miles and annual overhaul. In the former, attention is devoted principally to lubrication, the tightening of loose parts and cleaning, but in the latter the whole vehicle is disassembled and thoroughly rebuilt. After coming from the shop the vehicle is considered as good as or better than new. Although the general practice is to depend on the annual overhaul, the system followed in Philadelphia is based on unit overhaul. This is considered preferable because of the difference in the life of different parts. Parts are inspected and overhauled after 2000-mile periods, whereas the annual overhaul occurs after a mileage of from 40,000 to 75,000.

Schedules are governed by the volume of traffic and the speed between terminals, but because of the flexibility of the service ordinary variations can be smoothed out and obstructions to traffic, such as those due to fires, can be overcome.

Having secured the right equipment and proper maintenance, the next step is to select operators of the proper class, for service should be based on courtesy. As the employes are the persons who come into direct contact with the public their conduct has a great effect in producing good feeling or in alienating the good will of the passengers. [Printed in the June, 1924, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN A. F. MASURY[2]:—Suppose we take the main items, the body, the engine, the generator, the magneto, the transmission and the clutch, and put arbitrary figures on them. Assume that the motorbus was running 100 per cent, which part would last the longest? Which would be the first to break-down? That will give designers a chance to see what are the really weak features.

A. E. HUTT:—In a proposed system of unit overhauls, it is hard to say offhand what mileage can be obtained from any particular unit. I have two types of equipment running at the present time; while I might put one engine on one basis, I might put another one on another basis. The object is to assign the longest mileage that a unit will stand, with a reasonable expectation that no mechanical failure will occur on the road. The barometer of the mechanical department's efficiency is the absence of telephone calls because of trouble and breakdowns. In any equipment, the mileage allotment must be based on one's own experience or the experience of others who have operated similar equipment.

CHAIRMAN MASURY:—If the engine should go 50,000 miles, in general, would the magneto go, say, 30,000, the generator 20,000 and the clutch 10,000?

MR. HUTT:—I have already set a figure for the mileage of engines of one type of equipment at 50,000; I think that is a very good mileage to expect from any engine in double-deck motorbus service. Although some magnetos might run 50,000 miles without giving trouble, simply by being cleaned, the possibility of mechanical failure exists; either the bearings or some other part will go wrong. It seems to me that it would be a better policy, in view of the fact that it requires only a short time to take the magneto off, to do so every 10,000 miles, and I intend to do so until I see the possibility of extending the time, so that I shall know that the magneto is in absolutely first-class condition. The main object is to avoid delays on the road because of mechanical failure.

CHAIRMAN MASURY:—If the engine runs 50,000 miles, how far will the transmission and the rear axle run?

MR. HUTT:—If you will notice, I have not taken the rear axle as a unit. I have merely taken the differential assembly. I have taken the powerplant and the line through which the power is transmitted, the part that is getting the greatest use. I have not yet set any figure on the transmissions that we are operating. I have a figure on the clutches because I happen to have operated the same type of clutch in another city and know from experience that many have run for 70,000 miles without any trouble whatever; so it is perfectly safe to put those clutches on a 50,000-mile basis.

I have some other motorbuses that have a different type of clutch and, although the greatest distance that any one has run is 6000 miles, I have already experienced clutch trouble; I think that if I am able to put a 10,000-mile limit on those motorbuses, I shall be lucky; the inference, of course, is that when designing your own

[1] M.S.A.E.—General manager, Philadelphia Rural Transit Co., Philadelphia.

[2] M.S.A.E.—Vice-President and chief engineer, International Motor Co., New York City.

vehicle, stick to the type that you can put the longest mileage on.

CHAIRMAN MASURY:—Does Mr. Fielder's company overhaul motorbuses on the basis of mileage or of time? Is the clutch the most troublesome unit to fix, or the transmission, or the rear axle? In general, what is the weakest unit that motorbus operators have to contend with? Perhaps we shall agree that the lighting is the worst unit; at least, we hear considerable about it; maybe it is the magneto, perhaps the transmission.

MR. HUTT:—If the chairman wishes to know the item in motorbus operation that gives the greatest amount of trouble, I shall have to admit that it is one that I have not put on this unit system at all, because it has to be fixed practically every day, that is, the brakes.

However, with the growth of this industry I am looking forward to a radical change in the design of brakes for motorbuses. I think it will call for something far more efficient, far better built, than has ever been put into passenger cars. The reason I say so is that we are limited by the amount of space in which to put brakes; yet the loads that we have to contend with are out of all proportion to the loads on passenger cars. If the brake-drums on double-deck motorbuses had the same ratio to the weight of the loaded motorbus that the brake-drum on a passenger car has to the weight of the loaded car, the drums would have to be considerably larger in diameter than the wheels, if such a thing were possible.

R. E. FIELDER[3]:—It sounds logical to expect an engine to last longer than the brakes or the clutch, or some other part of the mechanism that is used several thousand times a day; yet an economic factor must be faced. If you are running several hundred vehicles and put 50 or 100 of them into service in 1 month, it stands to reason that you cannot bring 100 engines into the shop for overhauling just because they all have run 40,000 miles. You must arrange the overhauling program in such a way that it can be carried out by the minimum mechanical force and the minimum size of shop, and also distribute the material supplies over even periods of time. That is why I believe the annual-overhaul system to be better than the mileage-overhaul system.

If you have 365 motorbuses, you must overhaul from 5 to 7 of them per week regularly; and, knowing the regular amount of work to be done, you can arrange the mechanics, the storeroom supplies and the shop facilities to meet such an amount of work.

With regard to Mr. Masury's questions, of course the things uppermost in an operating man's mind are the parts that are wearing at every movement of the controller's hand. You start the motorbus by using the clutch; then the gears, spark-plugs, fan-belts and ignition-system all begin to work. When you stop the motorbus, you slip the clutch, put the brake on, change the gears and retard the speed of the engine, all of which again affect the brakes, clutch, spark-plugs, ignition-system, fan-belts and things of that kind.

Those are the things that need the greatest attention on the part of the designer. They should be out of all proportion to what is used in passenger-car work or even in truck work for that matter, because a motor truck usually picks up a load, carries it from 50 to 100 miles and puts it down; the only stops it makes are caused by traffic conditions or crossroads. In motorbus work you must use all those particular items every time a passenger is picked up; and a motorbus may carry 500 or more passengers a day.

With regard to what unit will give the greatest mileage, I would rather answer in this way: A motorbus should be arranged by the engineers and the designers so that the lives of all the units shall have the same length, because an annual overhaul should be made, if it is to be done economically, at a time when all the units need attention. It is not economical to find that the engine needs a 50,000-mile overhaul, while the bearings in the transmission or the rear axle may run for another 3 months, because you are throwing away 3 months' life; and if you do not throw it away you will bring the motorbus in again 3 months later for 50 per cent of the overhauling work.

So, the thing to do in designing is to balance the wearing qualities of all the units so that they will equal one another in performance.

W. E. MARTIN[4]:—Although we have had 7 years' experience, it has been mostly on motor trucks; it has been only in the last 2½ years that we have actually operated motorbuses. We now have 38 motor vehicles in operation, that is, 35 motorbuses and 3 trackless-trolley buses. We have 4 double-deck Fifth Avenue-type 51-passenger motorbuses that have gone possibly 60,000 miles. We have just completed overhauling and repainting them. Brakes have been the worst unit, but other units seem to wear in proportion. We are using an annual overhauling system like that of the Fifth Avenue Coach Co.

As to our three trackless-trolley buses, I think that outside of those on Staten Island, not more than three vehicles of this type had been operated previously in this Country. We have a peculiar situation. First, the road is in very bad condition. We have a narrow hilly rough road with a crown in the middle. We began with a very fast schedule but, finding that we could not maintain it and keep the equipment in shape, we cut down the schedule to something like 9 m.p.h., on the average. But we are still having trouble owing to the design of the vehicle.

As to the gasoline motorbuses, we began with 12-passenger Garfords, in July, 1915. In those times they used a truck chassis and a makeshift body. We ran those motorbuses 2½ years and they became obsolete. Later we bought 20 White Model 2030 buses. We operated them from 1917 to 1922, and then laid them aside, completely overhauling and converting them into motor trucks for the railway. Some of them have covered about 150,000 or 160,000 miles. We are now overhauling our other single-deck vehicles. We had some special-design single-deck buses built by the Republic Truck Co., with Knight engine, Clark 2D axle and Brown-Lipe transmission. Those we are overhauling now.

CHAIRMAN MASURY:—How far, in general, have the trackless-trolley buses run?

MR. MARTIN:—About 45,000 miles.

CHAIRMAN MASURY:—You have had motorbuses of several types. What do you think of the comparison?

MR. MARTIN:—A number of improvements have been made in trackless-trolley buses that are not in ours.

CHAIRMAN MASURY:—The motorbuses you had before were more successful than the trackless-trolley buses?

MR. MARTIN:—Yes, much more so; but the road conditions militate against the operation of the trackless-trolley buses.

CHAIRMAN MASURY:—Do your motorbuses negotiate those roads better than the trackless-trolley buses?

MR. MARTIN:—Yes; they are more flexible than the trackless trolley buses.

[3] M.S.A.E.—Chief engineer, Fifth Avenue Coach Co., New York City.

[4] Superintendent of automotive equipment, United Railways & Electric Co., Baltimore.

CHAIRMAN MASURY:—Your motorbus operation is much more successful than that of the trackless-trolley bus, is it not?

MR. MARTIN:—Yes.

CHAIRMAN MASURY:—Suppose you could lump the several makes together; which part would give the most trouble? Would it be the clutch or the brakes?

MR. MARTIN:—The brakes and the lighting; the lighting first, then the brakes. The other parts probably are equal.

E. W. TEMPLIN[5]:—What is the maximum schedule-speed that can be maintained and passengers be hauled comfortably?

MR. HUTT:—That depends, first of all, on the type of equipment and, naturally, on the size of the engine. It also depends on the volume of traffic on the route; in other words, on the number of stops. It also depends on the nature of the route, that is, the grade that you must contend with. One big system had an average speed of 8.6 m.p.h., and another had one of over 12. In Detroit we had an average speed of a little more than 10 m.p.h. I am hoping to make an average speed of 12 m.p.h. in Philadelphia, in spite of the traffic. For that reason we intend to use 100-hp. engines. Although we may spend more money for fuel, we shall save in fixed charges and platform help.

MR. FIELDER:—The average operating speed is, undoubtedly, as you all realize, a question of traffic conditions. Our average operating speed below 57th Street through Fifth Avenue is about 4.3 m.p.h. Our schedule speed is about 8 m.p.h. You can estimate what the average speed at about 60th Street is.

High speed in passenger motorbus operation has been demonstrated to be a success, I believe, on the Pacific coast and on highways elsewhere, particularly in inter-urban work, in which some motorbuses travel at 45 m.p.h. Just what the limit of speed of those motorbuses is, I am not in a position to state. You can probably answer the question yourselves if you study the problems of acceleration and retardation of the vehicle; find out what a 150-lb. passenger can stand in the way of deceleration. You can gather from these remarks what the speed for safe operation would be, within the limits of the motorbus length and the ability of the brakes to stop the vehicle, especially in New York City where the brake is used every 200 ft. A vehicle like those Mr. Hutt has, weighs 25,000 lb., fully loaded. The vehicle speed must be handled very conservatively if you wish to keep down the accident account. Accidents are very expensive for public corporations.

QUESTION:—Is the Knight-type engine best suited for motorbuses? If so, why?

MR. FIELDER:—During the last 14 years we have operated several hundreds of both poppet-valve and sleeve-valve engines. Mr. Hutt has had an experience similar to mine and the answer has always come, not from the engineering or the scientific side of the industry, but from the man in the operating department.

If you have 100 motorbuses and 20 men to maintain them in service, and those motorbuses are doing from 100 to 120 or probably 150 miles a day, and they come in at night, probably at midnight, maybe two o'clock in the morning, to be inspected, and a driver writes "Missing on such and such cylinders," and notes a few other troubles, and the road inspector reports the engine as being excessively noisy, and the police report likewise, and you must take off the cylinder-head and grind in eight valves, and probably adjust the tension of valve-springs, you realize that attending to 800 valves is rather difficult. Such things do not happen with sleeve-valve engines; they never need grinding in. Carbon begins to form on the side of the sleeves and gives a good hard surface; and carbon is a good bearing surface. You will find that you can run those sleeves probably to the 30,000-mile limit that Mr. Hutt is talking about without even touching them; that is an item in operation that is of value to the man who must maintain motorbuses. It is an item outside the relative mechanical efficiency of sleeve-valve and poppet-valve engines.

MR. HUTT:—I operated a fleet of Knight-engine cars at Detroit. When I came to Philadelphia, I resolved to try a different type of engine. I had had considerable trouble with the Knight engines that we had there, the main trouble being with the bearings; we had a terrific oil-consumption and, therefore, a great amount of trouble with carbon forming in the exhaust-ports. I thought I could get overhead-valve engines with absolutely interchangeable heads, that I could replace the heads without trouble and that this would solve the difficulty.

Since getting those motorbuses, I have obtained a certain number of motorbuses having Knight engines of the same type I had before, but since that time I have had a considerable amount of engineering work done on them. I am prepared to reverse my opinion regarding engines. The Knight engine that I have today, that is, the old R & V Knight as improved by Colonel Green, is vastly superior to the engine I had, or to any other engine that I know of for motorbus operation, because of the very great simplicity of its maintenance. We have run 10 of these motorbuses now for 30,000 miles and have practically never touched them. We took the carbon out of the exhaust-ports after the first 25,000 miles, and there was not much of it at that.

I can say to anyone who wants to maintain a fleet of motorbus engines that nothing is cheaper or easier to maintain than a well designed and well built Knight engine.

QUESTION:—It is reported that the ports on Knight engines must be cleaned frequently; also that sleeves must be renewed about every 6 months. Can Mr. Hutt or Mr. Fielder throw any light on this?

MR. HUTT:—When I was in Detroit, we used to scrape carbon out of the exhaust-ports, sometimes every 5 days, in other words, every 600 or 800 miles. They would block up so badly that one could not put a pencil through them. No wonder the drivers reported the engines bad. We took the carbon out of the exhaust-port of the first engine here after running 25,000 miles, and only one cylinder had to have it done. That goes to prove, as Colonel Green said to me, "When you put the same engineering and brains into the Knight engine that have been put into the poppet-valve engine, you will 'lick' the world." I am beginning to think he is right, at any rate as regards motorbus operation.

About the sleeves' being renewed every 6 months, that will depend on the service in which the motorbus is used, and on how well the sleeves are made in the first place. It is not only a question of machining them accurately, but of seasoning them during the process of machining and of keeping them properly; you cannot store them in a bin on their sides like so many bolts, because they will warp out of shape. The sleeves of a motorbus engine that will probably run from 50,000 to 75,000 miles in a year, as they are made now, will not need to be replaced at the end of 12 months, let alone 6 months.

QUESTION:—What percentage of decrease in the area

[5] M.S.A.E.—Engineer, motor-coach division, American Motor Body Co., Philadelphia.

of the exhaust-pipe, between the engine and the muffler, owing to carbon formation, is noticeable in overhauling after 2000 miles? Does this cause the engine to overheat?

MR. HUTT:—I should say, without having checked it, that the decrease in the diameter of the exhaust-pipe in 2000 miles could not be measured. The only place where I found that carbon formation interfered with the escape of the exhaust gases was in the heater pipes, not the muffler pipe, because they are restricted and the flow is not so fast. I know of no case in which a motorbus has lost power through the formation of carbon in the exhaust-pipe.

QUESTION:—What are Mr. Hutt's views on engine starters?

MR. HUTT:—Motorbuses here were originally built without engine starters, and many are still built without starters, the theory being to make the vehicle as simple as possible, to leave off anything that is not absolutely necessary. I feel that, as the engines become larger, we must have starters. In the small fleet that we are operating, I do not know whether one-quarter of the drivers we have at the present time could crank six-cylinder engines.

CHAIRMAN MASURY:—You mean with all the sleeves in?

MR. HUTT:—All the engines that we are operating now do not happen to be of the sleeve type. It is unfortunate that we should have that complication, but it has been a necessity.

QUESTION:—In what manner do the brakes fail so that they require daily attention?

MR. HUTT:—I will qualify my remark about brakes. I have two sets of vehicles; one has given us considerable trouble regarding brakes and the other has not. A large amount of very fine work was put into the brakes of one type of vehicle and these brakes are running from overhaul to overhaul with practically no adjustment at all, a thing that I did not know of some years ago.

Some years ago, out of every 100 calls that we got for trouble on the road, about 90 per cent were due to brakes. Very much finer methods of making the brakes, that include even the grinding of the lining after it has been put on, so that the brakes can be set-up practically with only a few thousandths of an inch clearance between the brakeshoes and the drum, have been responsible for the wonderful performance of the brakes to which I am alluding.

I have another type of vehicle; it is heavier and the linings sometimes wear off in 1 day of operation. I think that it is due to a slight error in the design of the brakes, which is being corrected at the present time. I believe, however, that one of our main troubles is that we do not have enough brake-lining area for the loads we are trying to stop. I will repeat what I said here a month ago, that I look for a solution in this way: Though I do not see the necessity for four-wheel brakes' acting in unison on double-deck motorbuses, still I see a great possibility in putting four-wheel brakes on motorbuses for the sake of getting additional area, utilizing all the area on the rear-wheel drums for the service brake, and putting the holding or emergency brake on the front wheels, to be used only as an emergency brake. One of the reasons I have for saying this is that double-deck motorbuses do not travel at great speed. I doubt if anybody would have the temerity to run them over 30 m.p.h. on the straightaway. No driver, if he has sense, will attempt to turn a corner fast with a double-deck motorbus. He is liable not to need any brakes at all as the friction between the side of the motorbus and the road will stop it. If that theory is correct, the only time we will need an emergency brake is when running straight at the maximum speed of, say, 30 m.p.h., when the four-wheel brake, whether equalized or not, will be ample. If we put service brake on the rear wheels, taking advantage of all the area there, naturally we shall reduce the unit pressure on the lining, and consequently make the time between brake adjustments much longer.

QUESTION:—What is the maximum grade of roadway consistent with safety of operation? Should 5 per cent be exceeded or reached for lengths of from 0.5 to 1 mile?

MR. HUTT:—I am facing that question myself in Philadelphia where certain localities have been looked over with a view to running double-deck motorbuses. Although I should not mind going up some of those grades in a double-deck motorbus, I should not like to come down. I think that 6 per cent is the maximum grade over which a double-deck motorbus should be expected to operate. That is a pretty steep grade.

QUESTION:—Is frequency of headway more important than large carrying-capacity, from the standpoint of net profits?

MR. HUTT:—There is a limit to which you can cut down the frequency of service. You might say, "We have so many hundred persons to carry per hour; we will build a vehicle, run one every half-hour and carry them all." The people will not wait a half-hour. They will wait only a reasonable length of time. So there must be some mean between the carrying-capacity of the vehicle and the headway.

Undoubtedly a field exists for a motorbus of very large carrying-capacity; I can visualize one carrying 100 passengers on certain routes, but on others I cannot, because it would mean a motorbus practically every 20 min. or every ½ hr.

QUESTION:—How can double-deck motorbuses be operated by one man, with the driver's lack of knowledge of the movements of passengers on the upper deck?

MR. HUTT:—I have never anticipated running double-deck motorbuses with one-man operation before we shall have a vehicle that we consider safe. When operating in Detroit, I have seen the need of just such a vehicle for lines that had a very small amount of riding after 7.30 p. m.

We have a vehicle in Philadelphia of such a construction that nobody on the upper deck can get his head knocked off unless he gets out of his seat and stands in the aisle; in addition, a signaling device notifies the driver, not the conductor, immediately if anybody gets into the aisle. When going under a viaduct or a bridge, the driver turns a switch that lights a green light and, so long as that light is burning, the driver knows that everybody is seated. The moment the light disappears, he stops. The only way in which persons can get into trouble on the upper deck is by standing up and getting their heads knocked off; if you can stop that, you will have avoided the whole difficulty. This system consists merely of a lamp at the rear end of the upper deck that focuses a beam of light down the aisle into a little periscope, and the beam is carried down to a bull's-eye within the vision of the driver. He does not have to be actually looking into it; it is not in front of his face, and all he need do is be conscious of that green light and stop if it disappears.

QUESTION:—If a 10-cent-fare double-deck seat-for-every-passenger coach-service parallels a trolley route, what changes, if any, will occur in the trolley traffic?

MR. HUTT:—An idea prevails in certain quarters that

if a motorbus line parallels a street-car line, the street-car line must go out of business. It is no such thing. I will not deny that the motorbus line will take a certain percentage of passengers away from the street-cars, but it will create for itself an entirely new patronage. The motorbus provides a different class of transportation; it furnishes a seat for each passenger, and many persons who own one, two, or three cars will ride in a motorbus and will not ride in a street-car, simply because they will not be jammed in in street cars. If the street-railway companies had to provide a seat for every passenger, they would have to get a higher rate of fare than the motorbus companies get.

We stole a certain number of passengers from the Jefferson Avenue line in Detroit, but we created a greater riding-habit and, after a while, the thing seemed to balance itself and the street-car company, though it lost a few riders, was not affected materially. We got all our patronage from persons who ride in private cars, and we benefited the city by keeping their cars out of the business district. It would be a good thing for Philadelphia if more persons would leave their cars at home instead of parking them around the City Hall.

QUESTION:—How does the speed of the motorbus affect the necessity for overhauling? Does a motorbus operating at 9 m.p.h. run 33 per cent longer than one at 12 m.p.h., without the necessity for overhauling? Is the wear in direct proportion to the speed?

MR. HUTT:—It would be useless to deny that the higher the speed is the greater the wear will be, but the item of maintenance in the larger companies is very small when compared with the cost of platform help. When I left Detroit the total cost of maintenance of the motorbuses, bodies and chassis, including all the overhauls, was less than 3 cents per bus-mile, and the cost of platform help was 14 cents per bus-mile. So, if the cost of maintenance were increased, say, 0.5 cent per bus-mile and the cost of platform help reduced 2.0 cents per bus-mile, there would still be 1.5 cents to the good. As I said before, it is the total cost of operation that we are interested in.

DR. H. C. DICKINSON[6]:—During the last year, in going through the plant of the London General Omnibus Co., one thing that appealed to me particularly was the system of standard sizes and continuous maintenance, which I did not know was in operation anywhere in Great Britain. For instance, they have nine standard crankshaft sizes, 0.5 mm. (0.19685 in.) apart, and each shaft is reground nine times before it is discarded. There are three cylinder sizes. The annual overhaul that has to be undertaken on account of the police regulations involves taking the vehicle all to pieces and distributing the parts entirely at random and reassembling them entirely anew. There is no such thing as the life of a vehicle; that is, the vehicle may go to pieces, may be discarded in parts, but the unit never disappears, so to speak.

CHARLES FROESCH[7]:—Mr. Hutt's views on successful motorbus transportation are very interesting. While they deal mostly with heavy transportation needs as experienced in the few larger cities, they can be applied to any case of the common carrier.

I think, however, that before we can successfully operate the 150-passenger super-motorbus that he mentions, we shall have to revise our city-planning systems, rebuild our highways and redraft traffic-control regulations to accommodate these vehicles. It is not only a question of the street space occupied per passenger transported that counts but also the rate of speed of the transport. In other words, the rate of speed of traffic-flow is, I believe, more important than the unit encumberment. A fleet of single-deck one-man-control motorbuses moving at a greater rate of speed might in many cases be more efficient than the slower-moving double-deck vehicles; and, while it is more economical to use double-deck two-man-control motorbuses during the peak loads, standard 25-passenger motorbuses on pneumatic tires would prove more economical for non-rush periods and certainly expedite traffic-flow.

It was my good fortune last year to make an actual survey of vehicular traffic in an Eastern city having a population of over a half-million people. Observations and traffic counts were made during the rush-hours while the city was in the grip of a complete tie-up of street railway facilities, and also after normal conditions had been resumed. A comparison of the data collected revealed the amazing fact that the absence of trolleys on the streets permitted an increase of traffic-flow and speed of from 10 to 16 per cent on the wider thoroughfares, and of as much as 43 per cent on the narrower streets during the rush-hours in the congested areas.

From this it was concluded that if trolleys could be operated from central terminals or predetermined points on express schedules to the various outlying residential districts, leaving the needs of the congested areas to be taken care of by motorbuses, congestion would be relieved and jams of the first magnitude eliminated. Of course, it must be said here that in this case the motorbuses and trolleys should be operated by the same company, but under separate divisions, to render the maximum service possible to the riding public and to eliminate a tie-up of transportation facilities.

Mr. Hutt's mileage-basis idea is excellent, but it assumes one factor that varies with the equipment. While I agree that time is not the proper factor to consider in the case of overhaul, does not a mileage system for each unit require more clerical work and accounting? I think that the chassis should be overhauled as a unit because a definite relation exists, so far as work is concerned, between its components.

R. S. BURNS[8]:—I believe that Camden is far ahead of Philadelphia when it comes to transportation, in that we have more motorbuses operating in Camden than are in service in Philadelphia. Transportation by motorbus today is the modern means of transportation.

In Camden we have trolley lines and motorbus lines operating on the same street. Some of the trolley fares are 5 cents and the motorbus fares are 7 cents. You can go over to the ferry at any time and see motorbuses operating on the same lines with the 5-cent trolley fare; and you will find that the people prefer the motorbuses. When the Public Service Commission put the 5-cent fare into effect, the general impression was that it would put the motorbus operators out of business, but it has not affected them at all; I believe the reason that the people prefer motorbuses is that transportation is quicker.

We have a line in Camden that is a little more than 4 miles long; it just takes 22 min. to make the 4 miles from the ferry during the rush-hours. I do not recall what the time is on the trolley. Speaking of the mileage of motorbuses, I have not heard anyone here claim more than 50,000 or 60,000 miles for a motorbus; that is, as to the life of it, or the mileage he is getting out of it. We can show you motorbuses in Camden that have cov-

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[7] Jun. S.A.E.—Designing engineer, Mack Trucks, Inc., New York City.

[8] Traffic supervisor for the City of Camden, N. J.

ered as many as 250,000 miles and are still operating on a fast line. The route is 22 miles long and they make it in about 90 min.

The man who operates that line has a motorbus that has been in service for 22 months and has never been overhauled. That motorbus makes four trips per day. But, on the other hand, the man has a mechanic at each end of the line who looks after that motorbus. If a wheel is a little loose or wabbly, the first thing the mechanic does is to see whether it is the tire or a nut is loose on the wheel or what the trouble is; in addition, to maintain the service, that man has a motorbus standing at the end of the line which he uses as a waiting-room. At the other end of the line is the garage, in which he always has a spare motorbus.

The system of operating motorbuses in New Jersey is very different from that in Philadelphia. Camden has a motorbus ordinance; in fact, almost all the towns and cities in New Jersey where motorbuses operate have motorbus ordinances; a man must first apply to the city to get a license; after the city has granted approval, the application must go before the Board of Public Utility Commissioners.

At the present time the motorbus supervisors of the State of New Jersey are working on motorbus specifications, a very important thing for the State for the simple reason that the towns and cities as a rule also have motorbus specifications; in other words, a man might travel in Camden, where they have a motorbus specification and, when he goes to Merchantville or some other town, he might find a different motorbus specification. The result is a conflict.

In the standardizing of a motorbus, the recommendations that the supervisors are making really do not go very far into the construction of the motorbus, but I should like to enumerate some of them. The first is the body specification: a maximum length of body, overall, of 21 ft., the bumper not to extend more than 4 in. beyond the body, a minimum length of 16 ft., a maximum width of 7 ft. 10 in., outside measurement, and a minimum of 7 ft., a maximum height, inside measurement, from floor to ceiling, of 6 ft. 6 in., and a minimum of 6 ft. 4 in.

G. H. SCRAGG[1]:—In specifying standard body measurements such as have been mentioned, is there not a tendency to increase the cost of the body or the chassis to New Jersey operators, inasmuch as a factory manufactures to meet the greatest demand of the entire Country? Because of different conditions in Minneapolis, we will say, where a body seating more persons may be needed, they may find the best all-round body is 23 ft. long. If various States specify different sizes of body, we would never be able to get quantity production. The result will be more expensive bodies.

Regarding the point that no bumper may extend more than 4 in. beyond the body, it is common practice in the Far West, where routes run sometimes 70 to 80 miles between towns, to carry spare tires, usually at the rear. Room must be allowed for a standard tire-bracket. It may not be necessary to carry a spare tire in New Jersey because of the short distances and because tires are serviced by a service wagon, but in the Middle West and the Far West a spare tire is carried because it is needed. The proposed New Jersey specifications would necessitate different designs for the bumper and the tire carrier, which would increase the cost of production.

MR. BURNS:—The maximum length that will be recommended to the Public Utilities Board is 21 ft. In Jersey City, Newark, Paterson and similar places, lines can be operated with large motorbuses, and on some lines a motorbus cannot be operated; that is why this specification gives the maximum and the minimum. When a license is issued to the operator, the city specifies the size of body that will be allowed on that line; if it finds that a 16-ft. body is better than a 21-ft. body, it will specify a 16-ft. body; if it finds that a larger body would be better adapted to that line, it will specify a larger body. In other words, every line will have a standard-size motorbus.

In Camden we had about 120 motorbus operators and it was very unsatisfactory for one man to have a 16-ft. car-body and another a 20-ft. car-body. Under the system that was in effect, it was necessary that the drivers pool their earnings; a man having a car with a 16-ft. body would expect as much money from the pool as a man with a 20-ft. car-body. This caused more or less contention and is the reason that this plan was adopted.

It will not cramp the engineer's style because most makes of motorbus that are operating today are 19 ft. 5 in. overall. The White Co. motorbuses are not much larger than that. Engineers can choose dimensions between the lengths specified; they do not necessarily have to stick to 16 or 21 ft.

The next recommendation was that a partition of wood and glass be located behind the driver's seat, installed to allow ventilation at the top. The reason that was suggested was that drivers used to have their friends ride with them on the trips; getting the drivers into trouble and causing accidents.

The ventilating system is very important on motorbuses. One-half the motorbuses that are constructed today do not have enough ventilation; the windows and the windshield steam-up. I believe that a great many accidents are caused by the fact that drivers do not like to open the wind-shields. It has been decided to leave to the municipalities the determining of the best ventilating system to adopt; but so far we are at sea.

Another specification was that grab-handles must be located inside the vestibule of the motorbus and be bolted on. The reason for putting them inside the motorbus is that many persons used to run for a motorbus, grasp the outside handles, and be dragged along and hurt.

In Camden a motorbus driver is not allowed to operate his motorbus with the doors open. The penalty for doing so is a $10 fine and on the third offense the city revokes the man's license. In several cases men who were standing in motorbuses when they hit obstructions fell through the open doorways and were killed.

Regarding the width of door, the specification is that the clearance in the entrance and the exit doors of a motorbus shall be 24 in.

Considerable thought should be given by members of this Society to the distance the body should extend beyond the chassis; that is, what the rear overhang of the body should be. We have a motorbus in Camden that has an 8-ft. overhang. The question is, Is it safe to operate that motorbus along the streets? The overhang was measured from the center of the rear wheel. I do not recall what it was from the rear end of the frame. All over New Jersey men who are not able to buy large motorbuses buy small ones. After they make a little money they put an extension on the frame, and put a second-hand body on. They carry probably 3 tons on a 1.5 or 2.0-ton chassis. That condition became so serious in New Jersey that it was decided that the overhang must be limited.

Another proposed specification is to the effect that the chassis shall run the full length of the body and extend

[1] Bus department, International Motor Co., New York City.

to the body sills. Another question that was brought up is the emergency door; whether it should be at the rear or at the side of the motorbus. Of course, that is a matter of opinion.

All motorbuses must be equipped with window guard-rails. Several cases are on record in New Jersey of women having had their arms torn off, on account of hanging them out the window.

The lighting and heating conditions are bad. In Camden and throughout New Jersey, if the heating system is not good, men put an oil-stove in the motorbus. This is one of the many things that you encounter when dealing with so many individual owners.

Considerable trouble has been experienced with noisy brakes. Unless the builders of these particular motorbuses take steps to remedy the trouble, cities will adopt ordinances that will eliminate those motorbuses. A noisy brake is a greater nuisance than a flat wheel on a trolley-car.

CHAIRMAN MASURY:—A point we seem to forget is that a great number of motorbuses are being operated by individuals and small companies. For instance, more motorbuses were sold in Newark by one motorbus company than the Fifth Avenue Coach Co. has operated in 20 years. More than 400 motorbuses were sold. In Detroit, 1,500,000 persons were carried by one motorbus operator, right under the nose of the traction company. The big field from the viewpoint of motorbus builders is not the large operators but the small independent operators. Such information as we have had given us in this paper will permit us to realize the motorbus that we want and make the design better and clearer.

QUESTION:—What is a fair year's mileage?

MR. HUTT:—A fair average for a double-deck motorbus operating in a large city is about 50,000 miles per year.

QUESTION:—What mileage is to be expected from the clutch before general overhaul?

MR. HUTT:—That depends entirely upon the type of clutch. I have seen a clutch come out at an annual overhaul, after doing 74,000-odd miles, that did not even need relining.

QUESTION:—How many years' experience are required of the motor mechanic in order that he may give expert maintenance?

MR. HUTT:—That is an interesting question. The big operating companies do not need experts at all. When one company I was connected with wanted another man in the general overhaul department, another floor-sweeper was hired and the floor-sweeper was promoted to another job. I can assure you that you can have a system such that you can graduate men who know absolutely nothing in the general-overhaul department and make them very efficient mechanics. That does not apply, however, to the unit-overhaul department, where properly trained mechanics are needed to do the work.

QUESTION:—In view of the development of small-wheel-diameter pneumatic tires, do you believe that they have a future in the design of double-deck motorbuses?

MR. HUTT:—Pneumatic tires have not been used successfully on double-deck motorbuses to date. I would be the last man to say that they cannot be used; nothing is impossible, but I do not consider them advisable at the present time.

QUESTION:—What mileage is to be expected from the transmission before the general overhaul?

MR. HUTT:—That depends entirely on the type of transmission used and the educational methods adopted in training the drivers. Some men might ruin a transmission in 2000 miles, but a man who had been properly educated in handling a motorbus might not harm it in 50,000 miles.

QUESTION:—What is the main cause for the failure of motorbus lighting? Is it because of the failure of the lamps, the wiring, the generator or the battery?

MR. HUTT:—It is probably due to them all. I think that enough care is not given to the wiring. I think you will find that the average motorbus is wired as people wire the bells of a house; they do not calculate what the wires must carry. If motorbuses are properly wired in the first place, wiring trouble can be avoided. The chief "trouble" with bulbs is that the passengers steal them. Ninety per cent of our bulb renewals are not caused by burn-outs, but by the bulbs being taken. Unfortunately, they fit the head-lamps of automobiles.

QUESTION:—Has the question of the emergency operation of motorbuses to replace interrupted trolley-service ever come up? Is such operation feasible?

MR. HUTT:—Yes. In Detroit the Department of Street Railways wanted to tear up the tracks on St. Jean Street for a distance of 2 miles and asked us to supply motorbus transportation meanwhile. We put in motorbuses and covered the situation for them with perfect success.

QUESTION:—What is the maximum schedule-speed obtainable, considering passenger comfort, with a 67-passenger double-deck vehicle on routes like Roosevelt Boulevard?

MR. HUTT:—I am hoping to attain a maximum time-table speed of 12 m.p.h. I am not in a position, however, to say whether I can do so. I have two types of equipment at the present time, one with a four-cylinder 4 x 6-in. engine and one with a six-cylinder 4 x 6-in. engine. Naturally, I must make the schedules consistently with the speed that the smaller vehicle is making. I have not yet had a chance to find out how much I can step that up for the larger vehicle.

R. E. PLIMPTON[10]:—It has occurred to me that, if we are to get better operation, we ought to have buses that will reduce the loading and the unloading time as much as possible. I am not sure that double-deck motorbuses will be the answer, under crowded city conditions, simply because so much time is consumed in climbing the stairs. They are very good for sightseeing. In certain parts of congested districts where they cannot turn, I suppose long-wheelbase single-deck motorbuses would not work, but in England they are used with an entrance and an exit, and we can, perhaps, with a six-wheel or some other design, handle the problem here in that way. A number of persons are trying to improve what I regard as the main limiting factor in motorbus operation now, the getting on and off of passengers. Different locations for the step-light are being tried; that is more important in country districts, of course. I was talking with an illuminating engineer the other day who is making time-checks to learn whether the best results can be obtained with the step-light at the left as you enter, or directly in front where one might kick it.

Other factors are the frame height, the door location and the number of doors. In New York City, on some of the so-called city-supervised lines, large motorbuses have a double-width door, so that two streams of passengers can use it at the same time.

Mr. Hutt refers to the pay-as-you-enter type of operation and says that it is common in street-railway work. I boarded three trolley-cars here this afternoon. Each one had a different system of fare collection. On the

[10] M S.A.E.—Associate editor, *Bus Transportation*, New York City.

first one, they took my nickel before I even saw the trolley-car; I went through a turnstile. On the second one, I stepped into the car where the conductor was waiting at the entrance; he did not take my nickel; he took my quarter and gave me some slips of pasteboard. The third was one of the "pay-as-you-pass" type. The conductor was in the center and took the nickel as I passed him and went to the rear of the car. The method of fare collection that should be used depends upon how the traffic comes in. In many places in city operation, if a crowd gets on downtown, they let the passengers crowd in and the fares are collected as the passengers go out; the process is reversed coming back. So, it is not safe to say that any one system is used on trolley cars, or that it should be applied to motorbuses.

In designing motorbuses, the traffic must be considered. The body, the frame, and everything else must be adapted to it.

A MEMBER:—I believe that large motorbuses have a future, provided they can be made so that they can be used in the streets of today. In other words, the motorbus must be controllable, so that it can get into and out of traffic readily without interfering with it. Such motorbuses are made, but people do not seem to take to them, merely because the usual type of motorbus has been used extensively and they do not like to change.

J. A. ANGLADA[11]:—The remark has been made that motorbuses can be substituted universally for trolley-cars. That, of course, is looking into the future, because the substitution is entirely an economic question. The trolley-operating companies simply cannot afford to discard the investment that they have, particularly in the downtown districts. Although the motorbus is the ideal vehicle for transportation in congested districts, a long time will elapse before we shall see the elimination of the trolley-car.

A story is told about Philadelphia policemen and the way they handle the semaphores on streets on which trolley-cars are operated. The policeman generally lets the traffic continue until a trolley-car comes close to the crossing, and then swings the semaphore; in that way he confers a boon upon the pedestrian; if we did not have trolley-cars in Philadelphia, we would be delayed in crossing the streets, because the policeman would not swing the semaphore at such frequent intervals.

Unquestionably the trolley-car, particularly in the downtown and congested districts of cities, must go, because it is not proper that vehicles operating on fixed rails should hold up traffic. Nor is it proper that persons wishing to get aboard or to get off the vehicle should be compelled to do so in the middle of the street. I think it has been proved conclusively, where motorbus operation has been handled by intelligent and well organized companies, that motorbuses can operate more cheaply than trolley-cars.

MR. FIELDER:—Regarding Mr. Burns' inquiry as to how long the overhang of a motorbus should be beyond the rear axle, I think that can be worked out fairly satisfactorily if the seating arrangement is studied. A wheel-pocket is located over the rear wheels, and, if a transverse seating arrangement is used, you must leave enough room between the wheel-pocket and the seat just behind it, so that passengers can put their feet there comfortably. That would amount to probably 30 in. from the center of the wheel-pocket to the seat-cushion. You would need also another seat behind that seat, which would be probably 28 in. behind the first seat. That would give the overhang for a single-deck motorbus.

In a double-deck motorbus, besides the spacing for those two seats you must add the length of the platform, which should be large enough to allow passengers to alight from as well as board the motorbus at the same time. That would require at least 40 in. So, it seems to me that an 8-ft. dimension probably would exclude operators of double-deck motorbuses.

CHAIRMAN MASURY:—I have tried to limit the overhang to 60 in. from the rear wheels. If a bus has an overhang of more than from 40 to 60 in., it should have snubbers. Limitations, such as the ordinance specification in one of the cities of New Jersey, requires a 90-in. overhang, because of the number of passengers to be carried; they say they have so many passengers that they must lengthen the overhang; they could not extend the wheelbase and get around the corners. It is one of those things that depend upon the condition of each particular street.

We certainly must look to the West for much of the development work. Motorbuses are running from Los Angeles to San Francisco, nearly 500 miles, and are maintaining schedules 1 hr. faster and $1 cheaper than those of a train.

One operator in San Francisco territory is operating 60 six-wheel motorbuses of his own manufacture, with 100-hp. engines; another one has eight-wheel motorbuses, carrying about 45 passengers. Between the Twin Cities, Minneapolis and St. Paul, schedules of 280 and 300 miles per day are maintained. The motorbus companies and operators have their own snow-plows and maintain the headway even during storms.

A MEMBER:—Those motorbuses have a bay window in the rear and a card table that you can engage in advance.

CHAIRMAN MASURY:—You can buy tickets in San Diego for delivery of yourself and baggage in Seattle, which is over 1200 miles distant, going all the way by motorbus. At the terminals are restaurants, comfortable rest-room, barber shops and the like. About 200 motorbuses pass in and out one of the terminals each day. Definite schedules are maintained.

[11] M.S.A.E.—Consulting engineer, New York City.

Lighting the Motorbus

By W. C. Brown[1]

Illustrated with Photograph and Drawings

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

ABSTRACT

General considerations that affect the attainment of adequate lighting are mentioned, it being stated that proper lighting of the interior of a motorbus is influenced by limitations peculiar to the service, such as vibration, scant headroom, a restricted energy supply and relatively large voltage-variations. Available types of bus-lighting equipment are analyzed as to their suitability, from six different standpoints that are stated. "Glare" is defined and means of obviating it are suggested, inclusive of a discussion of desirable types of finish for the interior with regard to reflecting surfaces.

The severe vibration produced by many motorbuses demands head-lamps of more rugged construction than that used for the headlighting of private cars. Eight essentials for motorbus head-lamps are specified. A very large percentage of the glare and poor illumination of the motor vehicles on the roads results from improper adjustment or the lack of any means for adjustment of the head-lamps.

Tail-lamps, stop and direction signals, step-lamps, trouble-lamps, lights for the signs and marker-lights are discussed. Standard incandescent lamps are recommended for use. The most suitable type of electrical system for motorbus service is outlined briefly, consideration being given to the wiring needed to minimize voltage-drop, switches, lamp sockets, fuses, generator and voltage regulator.

Desirable standards of service are being evolved rapidly. Appropriate standards have long been expected and, in many respects, required for all public utilities. Proper lighting is one of the important elements in satisfactory bus service, and is contributing to the growing public approval accorded this form of transportation.

In competition with other transportation agencies such as rival bus-lines or private cars, lighting plays a vital part in attracting and holding new passengers. Aside from the obvious drawing power of the well-lighted bus standing at the curb on a dark night, the warm comfortable appearance of the interior gives the passenger a sense of security and well-being. He can see the other passengers plainly, read the advertising cards and enjoy his newspaper in comfort. The trip seems shorter, jostling is reduced and there is less stumbling over baggage and similar obstructions. In addition, good lighting has the advantage of discouraging petty thievery and annoyance to unescorted women and reduces the likelihood of minor injuries with their resultant damage-suits.

Obviously, where the lives of so many persons are literally in the hands of the driver, good headlighting is of extreme importance. A proper tail-lamp is required. Electrically lighted signals, provided with means for keeping the driver informed that they are operative, minimize the danger from rear-end collisions in the event of sudden stops or turns. Colored marker-lights at the four corners of the body near the top help the approaching driver to estimate the available road space.

Interior Lighting

The problem of lighting the interior of the bus involves consideration of limitations peculiar to the service, such as vibration, scant headroom, restricted energy-supply and relatively large voltage-variations. Buses are subjected to considerable vibration, jolting and swaying, particularly when the routes covered include rough roads and bad pavement. Under these conditions vision becomes more difficult. For satisfactory reading facility, it is necessary to provide an illumination of from 4 to 8 ft-candles. In addition, illumination of a not very different order should be supplied for the upper side-walls and ceiling to provide a pleasant and cheerful appearance and to illuminate satisfactorily the advertising cards, that are a desirable source of revenue.

In buses having low ceilings, and especially in those equipped with cross-seats, proper location of the luminaires or lighting units to avoid the casting of shadows by the passengers on their own reading matter is as important as furnishing enough light. The best results are obtained by placing a luminaire over the center of the back of each cross-seat. With well-designed units in a bus having a light ceiling, the standard 21-cp. headlamp bulb gives an illumination on the reading plane which is in the upper part of the range already mentioned as necessary to sustain satisfactory reading facility. The intensity can be held within the range by proper maintenance, except when unusual voltage conditions occur. This arrangement is in all cases preferable to the use of fewer units equipped with lamps of greater candlepower.

Most buses in service today have insufficient generator capacity to permit the use of such a unit over every seat. It may be sufficient to provide only for 21-cp. units over alternate seats. Utilizing the best equipment, this arrangement gives an intensity that is in the lower part of the desirable range, and in service is likely to fall below it at times. Relatively little difficulty from shadows is experienced with such spacing and, considering all the cost and efficiency factors involved, it is substantially as satisfactory as using units with lamps of lower candlepower over every seat. It is important that the units be placed over the backs of the seats. If, for example, they are moved 1 ft. or more farther ahead in the bus, the reading matter in the hands of passengers in every second seat will be shaded.

Selection of the Luminaires

Available types of bus-lighting equipment are analyzed as to their suitability from six important standpoints that are stated in Table 1. When luminaires that rate high from the standpoints of lighting, glare and maintenance are used, the bus is attractive to people on the street as well as to those in the bus.

Satisfactory illumination for the passengers' reading matter and for the advertising space depends upon the

[1] Engineering department, National Lamp Works, General Electric Co., Cleveland.

total amount and the distribution of the light delivered by the luminaires. High output, or high efficiency, is of prime importance, the energy available being so limited. In general, an open reflector is a more efficient unit and distributes the light to better advantage than does an enclosed unit. From the standpoint of illumination of the advertising space and the bus ceiling, it is desirable to have approximately 20 per cent of the light output from the unit distributed above the horizontal.

Glare

Glare is defined as the interference with vision and the discomfort a person experiences from bright lighting units. It is especially marked when low ceilings bring the luminaires close to the line of vision of passengers in the rear of the bus. Therefore, it is very important that the glassware be of sufficient density and the illuminated portion of sufficient size to keep the candlepower low in the direction of passengers whose eyes ordinarily would be directed toward them; and also to avoid bright spots. The use of bare lamps in buses should never be considered. Moderately dense opal reflectors are preferable to those of light density. Open reflectors should be deep enough to shield the filament to at least 30 deg. below the horizontal.

Unlike carbon deposit in an engine, the coating upon

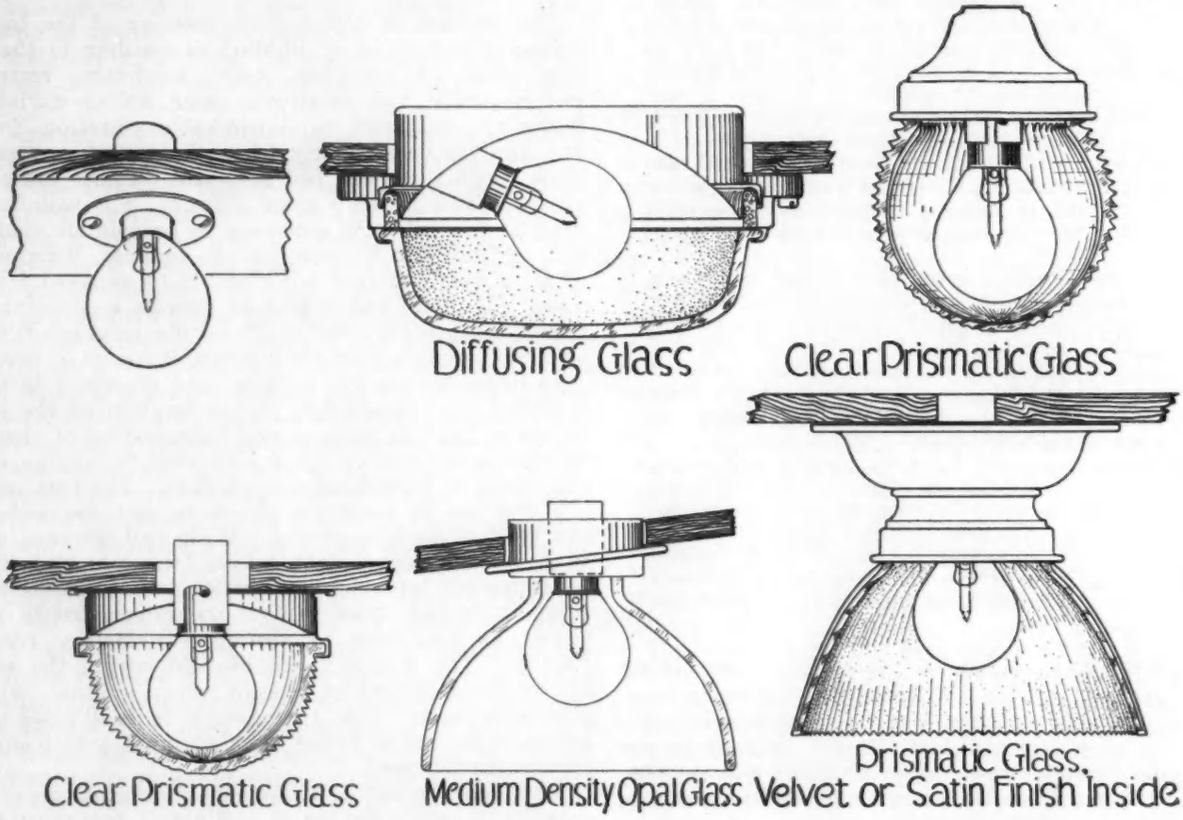

TABLE 1—A GUIDE TO THE SELECTION OF LUMINAIRES FOR MOTORBUS INTERIORS

Type of Luminaire	Rating from the Standpoint of					
	Illumination of Passengers' Reading-Matter	Illumination of Advertising Space	Glare	Maintenance	Obstruction Hazard	Theft of Lamps
Upper Left	*B*	*C*	*D*	*B*	*B*	*C*[2]
Upper Center	*B*	*B*	*C*	*C*[3]	*A*	*A*
Upper Right	*B*[4]	*B*[4]	*A*+[4]	*A*[6]	*A*	*A*
Lower Left	*B*	*B*	*C*	*C*[3]	*A*	*A*
Lower Center	*A*	*A*	*A*	*C*	*C*	*B*[2]
Lower Right	*A*	*A*[7]	*A*	*C*	*C*	*B*[2]

[2] Rating *A* if provided with locking socket.
[3] Rating *D* unless provided with dust-tight gasket between cover-glass and reflector.
[4] May fall to rating *C* or *D* if glass or reflector is inefficient.
[5] Rating *C* if clear cover-glass.
[6] Rating *C* or *D* unless provided with dust-tight gasket and glass with smooth outer surface.
[7] Rating *B* if clear glass.

the surfaces of the luminaires, caused by the gradual accumulation of dust, smoke and the like, produces no "knock" to call attention to itself. Hence, a large part of the light frequently is absorbed before the condition is remedied. Yet the cure is a very simple one. All that is needed is cleaning as regularly as the bus itself is cleaned. Many bus companies that are meticulous regarding the general condition of their buses are neglecting this simple addition to their maintenance schedule. The limited energy supply makes the conservation of the available light doubly important. The tight-fitting enclosed-unit with only one exposed surface, and that facing downward, is the most nearly ideal unit from the cleaning standpoint; dirt accumulations are small and cleaning is accomplished most simply and quickly. In the case of open units, three surfaces are exposed to the dirt, the lamp bulb, the inside and the outside of the reflector; hence, the effect of dirt accumulation is materially greater and cleaning is less simple, though by no means difficult. A frosted finish collects more dirt and adds to the work of cleaning.

The obstruction offered by the units and the theft of lamps are considerations of lesser importance in the selection of the best luminaires, and yet the possibility of injury to passengers in buses having low ceilings is a factor that becomes more serious with the deeper units and those having sharp edges. The enclosing units afford protection against unauthorized lamp removal. With all types of equipment, locking sockets give the maximum security.

Interior Characteristics That Affect Illumination

Dark-colored ceilings and upper side-walls should be avoided because they absorb much of the light that strikes them and detract from the appearance of the bus at night. White is, of course, the most efficient color. The reflection factors of the finish-colors used are: for white paint, 75 to 85 per cent; for light-oak stain, 35 to 45 per cent, and for dark-oak stain, 15 to 30 per cent.

Enamel finishes are less desirable than flat finishes on account of the spotty appearance caused by reflections from the glossy surface. This is illustrated in Fig. 1. On the other hand, flat finishes collect dirt and grease more readily and are more difficult to clean. The advantages of both are retained in a finish known as "semi-mat," often referred to as "egg-shell" finish. With some paints of this type the direct reflections are not objectionable; the surface is sufficiently smooth so that dirt is not collected readily and cleaning to restore efficiency is almost as easy as in the case of the regular glossy paint or enamel.

Head-Lamps

Satisfactory headlighting for motorbus service depends upon utilizing proper equipment and maintaining correct adjustment. The severe vibration found on many buses requires that the head lamps be of more rugged construction than many of those made for private cars. The following physical characteristics are essential:

(1) Housing of heavy-gage material constructed so as to obviate warping

(2) Reflector of heavy-gage brass, silver-plated and firmly fastened to the housing

(3) Focusing mechanism that will not rust together nor shift position under vibration, and a large conveniently located focussing-screw

(4) Tight fit between the socket and the reflector sleeve; also between the socket and the lamp base

(5) Dust and moisture-tight gasket between the cover glass and the reflector that will not loosen when the glass is removed to replace a lamp

(6) Cover glass firmly attached so that it cannot rotate from a vertical position

(7) Door fastened so that it can be removed easily for lamp replacement, preferably hinged, and with a clamping arrangement that can be drawn-up tight

(8) Solid substantial S.A.E. Standard mounting arranged so that the head-lamp can be aimed readily by loosening one nut and the aiming remain unaltered when the nut is tightened again

Fig. 1—The White Enameled Ceiling Is an Efficient Reflector and Is Easily Cleaned, but the Images of the Luminaires Give It a Spotty Appearance

Flat Finishes on the Other Hand Collect Dirt and Grease More Readily and Are More Difficult To Clean. The Advantages of Both Are Retained in What Is Known as the Semi-Mat or Egg-Shell Finish. In Some Paints of This Type Direct Reflections Are Reduced So as To Be Unobjectionable and as the Surface Is Sufficiently Smooth Dirt Does Not Collect Readily and Cleaning To Restore Its Efficiency Is Practically as Easy as in the Case of Glossy Paint or Enamel

A paper by R. N. Falge and W. C. Brown on the Importance of Better Automobile Head-Lamps and Proper Adjustment[8] gives further information.

To obtain the proper distribution of light on the road, an approved light redirecting device should be employed. The Eastern Conference of Motor-Vehicle Administrators has designated the better devices as "Class A." These are listed in Table 2.

Even the best of headlighting equipment may become as useless as the worst if improperly adjusted. A very large percentage of the glare and poor illumination so much in evidence on our roads today results from improper adjustment or lack of any attempt at adjustment. An immediate and far-reaching improvement in night-driving conditions would be brought about if drivers realize that, with the majority of head-lamps now in service, it is entirely possible and practicable to get good road-illumination and avoid objectionable glare by adjusting the head-lamps properly, and that drivers who make the proper adjustments without waiting for others to make them, not only remove the annoyance they are causing others on the road but provide for themselves a road-illumination that is better and safer, making it

[8] See The Journal, July, 1923, p. 25.

TABLE 2—UNIFORM APPROVED LIST OF CLASS *A* HEAD-LAMP DEVICES

The devices in this class have been approved by the Conference of Motor Vehicle Administrators, representing the following States, in all of which they are legal:

Connecticut	Massachusetts	Pennsylvania
Delaware	New Hampshire	Rhode Island
Maine	New Jersey	Vermont
Maryland	New York	Virginia

In some of these States other lenses or devices, in addition to those listed below, have been approved. If in doubt about the legality of your lens or device, communicate with your Motor-Vehicle Commissioner.

When properly adjusted, head-lamps equipped with any one of these devices will be legal in nearly all States.

Devices	*Focal Adjustment*
Alpheco	Principal
Bausch & Lomb	Principal
Benzer Type *A*	Principal
Brown Reflector	Special
Conaphore *F* Clear	Principal
Conaphore *F* Noviol	Principal
Dillon Type *I*	Principal
Dodge Bros. 8⅝ only	Principal
E. & J. Type 20	Special[9]
Flatlite Standard Reflector	Special[9]
Flintex	Principal
Ford *H* 8⅛ only	Principal
Guide-Ray Type *A* Head-Lamp	Special
Holophane 855	Principal
Hudson 8⅛	Principal
Lee Knight	Principal
Legalite *MIII*	Principal
Liberty Type *D*	Principal
Macbeth Type *D*	Principal
McKeelite	Principal
Miro-Tilt	Principal
Monogram	Principal
Osgood *B*-23	Special
Parab-O-Lite Type *FW*	Special
Patterson	Principal
Smith	Principal
Spreadlight	Principal
Standard	Principal

[9] Narrowest vertical spread.

easier to pass cars with glaring head-lamps, than is now the case when they have their bright lights on.

Fortunately, almost all non-glare devices in general use are designed for the same position of the bulb in the reflector, known as the "principal" focus position; as will be noted from Table 2. Proper headlighting is impossible if the equipment is not kept in good condition. Whenever a lamp is renewed, and oftener if necessary, the reflectors, the lamps and the lenses should be cleaned carefully.

The Tail-Lamp

The Society of Automotive Engineers and the Illuminating Engineering Society have promulgated specifications for adequate illumination of the rear number-plate, compliance with which is required by some states. Various manufacturers supply equipments which meet the requirements with either 2 to 4-cp. lamps. Glass, rather than celluloid or pyralin, should be used as a cover for the license-plate opening. The unit should be dust-proof and provided with a drain-hole at the bottom to allow the escape of any moisture that may collect inside.

Stop and Direction Signals

The electrically lighted signalling device is essential on the motorbus, and, because of the width of the body, two should be used, one on each side. A paper by R. N. Falge and W. M. Johnson entitled Stop and Direction Signals for Motor Vehicles[10] gives detailed information. The main requirements for a satisfactory signalling are:

(1) It should be sufficiently bright to compel attention in the daytime

(2) It should not cause glare great enough to interfere materially with the vision of the driver of the car behind

(3) The switch should operate so that the device will indicate the intention of the driver as to a change of speed or direction, or both, before any change has taken place

(4) It should be provided with some form of reliable indicator to keep the driver informed that the signaling device is operating

(5) It should above all be reliable, since primarily it is a safety device; and a minimum of attention should be required to keep it in operative condition

(6) Any parts requiring replacement should be readily available

Step-Lights

A suitable step-light assists passengers in entering and in leaving the bus, particularly on dark streets. It reduces the chance of accident and of annoyances such as stepping into mud-puddles. Where a door is employed, the step-light preferably should be connected so that it will be turned on automatically when the door is opened.

The Trouble-Lamp

For trouble-lamp, mounted on an extension reel that will allow it to reach to any point of the bus, the standard 21-cp. head-lamp bulb should be used. The unit should include a reflector with diffusing surface back of the lamp to shield the eyes of the worker from the direct rays from the filament, and to increase the light upon the work.

The Sign

With the box type of sign provided with a translucent cloth or other means for changing the wording readily, three 21-cp. lamps, equally spaced, give best results. However, the electrical system ordinarily is not adequate

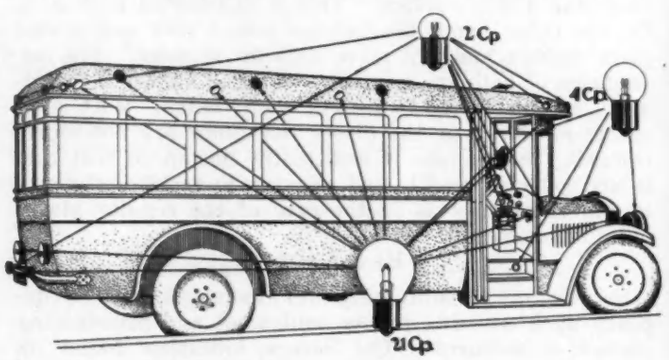

FIG. 2—THREE STANDARD SIZES OF LAMP WILL TAKE CARE OF MOTOR-BUS LIGHTING REQUIREMENTS

The 2, 4 and 21-Cp. Lamps Are Used in the Locations Shown. Table 3 Gives the Names of the Different Lamps

TABLE 3—RECOMMENDED CANDLEPOWER FOR THE VARIOUS LAMP POSITIONS ON A MOTORBUS

2 Cp.	4 Cp.	21 Cp.
Side	Auxiliary Head-Lamp	Head-Lamps
Marker	Step	Spot
Instrument	Sign	Sign
Signal-Indicator		Trouble
Fare-Box		Interior
Tail-Lamp		Signal
		Backing

[10] See THE JOURNAL, May, 1923, p. 475.

for this practice. Three lamps should be used in any event, even though it be necessary to drop to the 4-cp. size. The interior of the box should be painted white and sealed to keep out moisture and prevent accumulation of dust and dirt. A more effective form of sign is that in which the letters are made of translucent glass.

Marker-Lights

Bus bodies are considerably wider than those of ordinary passenger-cars. Marker-lights, mounted at the top corners of the body at the front, rear and sides, give the drivers of passing vehicles a measure of the

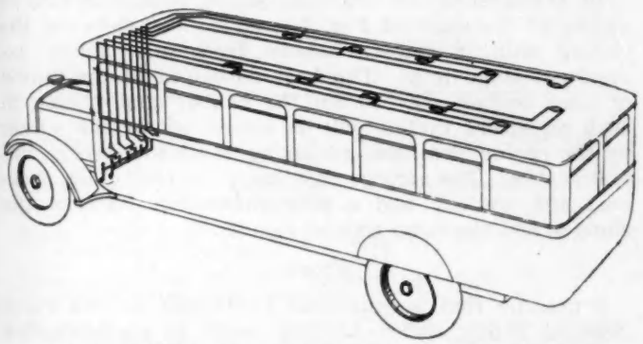

Fig. 3—Recommended Practice for Motorbus Lighting
In This Arrangement 11 Lighting Units Are Grouped on 4 Circuits Normally, but If the Demands for Energy Are Abnormal, It Is Possible To Reduce the Number of Units to 6 with Proper Spacing

road space left for them. The 2-cp. lamp behind the familiar Fresnel type of lens is sufficient for this service.

The Incandescent Lamp

Standard lamps should be used wherever possible, because of their important advantages of high quality, low cost and availability. To reduce stocks of lamps at terminals to the minimum and make various lamps on the bus interchangeable, the sockets should have uniformly either single or double contact, and preferably single-contact where a ground-return system is used on the chassis. Standard lamps of 2, 4 and 21 cp. are

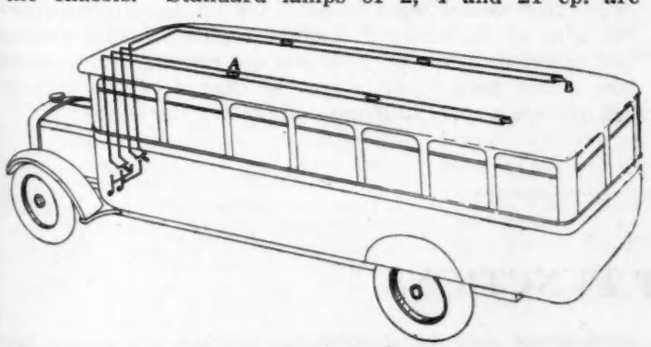

Fig. 4—Another Wiring Arrangement That Is Recommended
In This Scheme the Six Lighting Units Are Divided between Two Circuits

recommended for the various positions on the bus as shown in Fig. 2 and Table 3.

Electrical Systems

The electrical systems usually employed for bus service are 6 to 8 or 12 to 16-volt. From the standpoint of incandescent-lamp performance, the 6 to 8-volt system is preferable. The lamps are inherently more rugged and better able to withstand the severe vibration often encountered in bus service. Better headlighting results are obtained with the 6 to 8-volt lamp, as its filament is

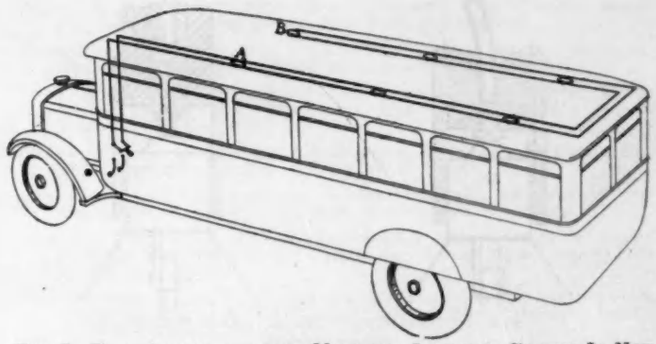

Fig. 5—This Arrangement of Motorbus Lighting Circuit Is Not Recommended
All Six Lighting Units Are Put on One Circuit in This Scheme

more concentrated than is that of the lamp having the higher voltage. It is recognized that other factors are to be considered in the choice of the electrical system for a bus. Not only does the question of the relative cost and size of the generator and starting-motor enter, but also the factor of the larger size of wire required for the 6 to 8-volt lamps.

Wiring

Voltage-drop in the circuit, which means less voltage at the lamp filament, has a far more serious effect upon

TABLE 4—WIRING REQUIREMENTS FOR MOTORBUSES

Wire Size, B. & S. Gage	Candlepower of Lamp *B*[11]				
	6 to 8-Volt 21-Cp. Lamps		12 to 16-Volt 21-Cp. Lamps		
	3 Units per Circuit	6 Units per Circuit	3 Units per Circuit	4 Units per Circuit	6 Units per Circuit
18	12	1	19	18	15
16	15	4	20	19	17
14	17	9	20	20	18
12	18	13	21	20	19
10	19	16	21	21	20
8	20	17	21	21	20

[11] Lamp A operating at rated 21-cp. Wire sizes should be such as to maintain at least 19-cp. on all lamps.

the candlepower of the lamp than is generally realized; a slight reduction in voltage produces a material reduction in candlepower. For example, with a 10 per cent drop in voltage, *one-third* of the candlepower of the lamp is lost. Hence, it is important to guard against voltage losses in the wiring and at the switches, fuses, sockets and connections of the circuits. Voltage-drop is proportional to the current. Motor-vehicle lamps, being of low voltage, necessarily draw a heavy current. The standard 6 to 8-volt 21-cp. lamp, for example, while taking only 18 watts, nevertheless *uses more current*

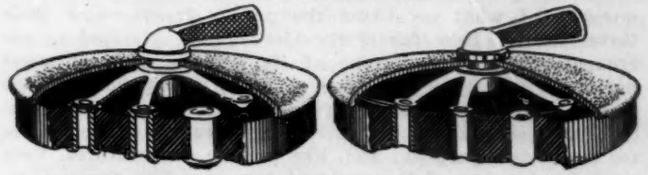

Fig. 6—Satisfactory and Unsatisfactory Types of Switch
A Good Switch, Such as That Shown at the Left, Has the Wiring Contact of a Knife-Switch and Generously Designed Spring Members and Opens So That Only Air Acts as the Insulating Material. If, However, the Current-Carrying Member Makes a Butt Contact and Slides along the Insulation as the Circuit Is Opened, as Shown at the Right, Particles of Insulation and Dirt Will Gradually Accumulate on the Surface of This Member, the Resistance Will Increase and Heating Will Result, Thus Drawing the Temper from the Spring Finger and Rendering the Contact Less Effective

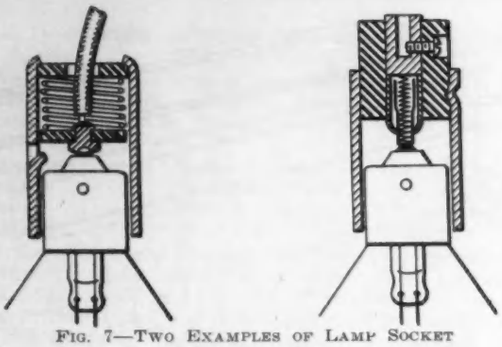

FIG. 7—TWO EXAMPLES OF LAMP SOCKET CONSTRUCTION

In the Socket at the Left, Which Is Designated as Good Construction, a Continuous Path for the Current through the Socket Is Provided as Is Also a Good Connection between the Plunger and the Lamp Contact. Poor Contact between the Sliding Plunger and the Sleeve Frequently Causes an Excessive Voltage-Drop in Undesirable Types of Socket, One of Which Is Illustrated at the Right

than a 300-watt lamp of the ordinary 115-volt type, and for equal candlepower-loss requires an even larger current-carrying capacity for the various parts of the circuit. Therefore, the wiring, should be of ample size, especially for the interior lighting system. Not only is all the light needed that the system can give but, without large wire, the last lamp of a circuit will be noticeably dimmer than the first. Wires of less than No. 14 B. & S. gage should not be used, for mechanical reasons. This size will assure not less than 19 cp. from each lamp if not more than four lamps are used per circuit on a 12 to 16-volt system. On buses with 6 to 8-volt systems, No. 10 wire is similarly required. Reference is made to Table 4 and to Figs. 3, 4 and 5. For the head-lamps, and the signal and the other lamps of 21-cp., No. 14 B. & S. gage wire should be used. All connections should be well soldered.

SWITCHES

A good switch, an example of which is shown at the left in Fig. 6, has the wiping contact of a knife-switch, and generously designed spring-members, and opens so that only air acts as the insulating material. If as shown at the right in Fig. 6, there is, in effect, a butt contact, with the current-carrying member sliding to make contact with the insulation as the circuit is opened, a gradual accumulation of material and dirt on the surface of the member is likely to occur with consequent high resistance and heating that draws the temper from the spring finger and thus renders the contact still less effective.

LAMP SOCKETS

Good socket construction, as shown at the left of Fig. 7, provides a continuous path through the socket for the current and a good connection between the plunger and the lamp contact. The springs cannot carry current and consequently are not weakened through heating. No material which would become unserviceable under moderate heat is used.

In the undesirable types of socket, one of which is shown at the right of Fig. 7, poor contact between the sliding plunger and the sleeve frequently causes excessive voltage-drop. The heat developed at the points of poor contact may soften the rubber composition to such an extent that it will be forced out of the socket by the spring pressure, rendering the whole socket unserviceable. The springs that carry current often overheat and weaken, and a poor connection between the plunger and the lamp contact results.

FUSES

A practice that is equivalent electrically to link fuses fastened firmly under binding posts is recommended rather than the use of cartridge fuses and clips employing butt contacts. Due to lack of cleaning action, small area of contact, corrosion, and electro-chemical action, the cartridge fuse is very often the source of considerable voltage-drop. If cartridge fuses are used, both fuse ferrules and clips should be nickel-plated to prevent electrolytic action.

GENERATORS AND REGULATORS

Because of the large lighting-load, the generator for a motorbus should have a capacity several times that provided for a private car. Such equipment is now available. In selecting the proper size, full allowance must also be made for ignition, starting and parking requirements. The electrical load by day is relatively so slight that means must be provided for preventing overcharging of the battery. Voltage regulators have proved best adopted to this purpose and are coming into general use. They tend to maintain the charge of the battery and provide a more uniform voltage for the lamps.

GOVERNMENT FUNCTIONS

IT is of the utmost importance that the American people should give serious consideration at this time to the question of what constitute the proper functions of their Government. How far is the Government justified in encroaching upon the income of its citizens and for what purposes? Is there not some canon of public finance that may be taken as a guiding principle? Government expenditures are simply the collective expenditures of the people for a common purpose; and, like private expenditures, they must be met out of the national income. The question is, then, what proportion of the national income shall the people contribute to the common fund for the promotion of collective activities, and what proportion shall they keep for private expenditures? Obviously, no fixed ratio can be set and no fixed rule would apply in all cases. Political conditions and environment, as well as the stage of economic development that the Country has reached, are among the dominating factors that determine this question.

It is probably not generally realized that at least four-fifths of the expenditures of the Federal Government are for war debt, army and navy, disabled veterans, pensions and other expenditures directly or indirectly due to national defense. It needs no argument to show that within reasonable limits expenditures for public roads and bridges, education and public health promote the general welfare and add to the productive power of the people. The same is true of activities for the promotion of industry, commerce and agriculture through the dissemination of information and by certain limited regulatory measures. It is obvious that all of these are undertakings that can be carried on more effectively and economically by collective action than by individual action.—Andrew W. Mellon.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10, and Aug. 10, 1924. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

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PICKENS, RUSSELL A., JR. (J) student, Tufts College, Medford, Mass., (mail) 117 Common Street, *Watertown, Mass.*

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ST. HORNOW, JOHN (A) superintendent of automobile equipment, Arbuckle Bros., 40 Gold Street, *Brooklyn, N. Y.*

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WOOD, EDWIN T. (M) metallurgical engineer, Wheeling Steel Corporation, *Steubenville, Ohio.*

Applicants *for* Membership

The applications for membership received between July 15 and Aug. 15, 1924, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communication from members be sent promptly.

ALLEN, EDMUND TURNEY, aeronautical engineer and consultant, Cosmos Club, *City of Washington.*

APPLETON, JOSEPH H., consulting and designing engineer, *Oshkosh, Wis.*

BAKER, W. F., chief draftsman of engine division, Willys-Overland Co., *Toledo.*

BEEH, LOUIS, vice-president, Robert Bosch Magneto Co., *New York City.*

BUCKLAND, L. J., managing editor, *Ford Dealers News, New York City.*

BUFF, CARL THEODOR, production manager, Deutsche Werke Aktiengesellschaft, *Spandau, Germany.*

BURTON, LIEUT-COL. F. H., Quartermaster Corps, *City of Washington.*

COLE, F. HARRISON, chief inspector, Apco Mfg. Co., *Providence, R. I.*

FISHER, URBAN A., vice-president, Standard Motor Truck Co., *Detroit.*

FRENCH, GEORGE F., Towson Body Co., *Detroit.*

GASCOIGNE, G. NORMAN, assistant sales manager, Dearborn Equipment Co., *Kalamazoo, Mich.*

GROCE, GARD D., factory engineer, Rolling Motors Co., *Cleveland.*

HAEFFNER, EARL W., technical supervision, Cedar Rapids Auto Supply Co., *Cedar Rapids, Iowa.*

HEIDER, HARVEY B., engineer, secretary and treasurer, Luce Cane Harvester Corporation, *New York City.*

HORNING, SAMUEL D., instructor in automobile mechanics, Monarch Auto School, *Tulsa, Okla.*

KAYE, LEROY A., assistant engineer, Stewart-Warner Speedometer Corporation, *Chicago.*

KELLY, DANIEL H., vice-president, U. S. Light & Heat Corporation, *Niagara Falls, N. Y.*

LAPSLEY, JOHN ALEXANDER, automotive engineer and draftsman, Yellow Coach Mfg. Co., *Chicago.*

MCDOWELL, ROY C., manager, Stephens Motor Car Service Co., *Freeport, Ill.*

OFLENLOCH, H. P., service manager, Federal Motor Truck Co., *Long Island City, N. Y.*

ONORATO, SAHAZAR E., service superintendent, George Campe, Inc., *San Francisco.*

OSTERMAN, CARL HANS, president, Aktiebolaget Hans Osterman, Birgerjarlsgatan, *Stockholm, Sweden.*

PRAY, LUCIAN, body engineer, H. & M. Body Corporation, *Racine, Wis.*

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STEWART, JAMES, automotive engineer and salesman, Vacuum Oil Co., *Wellington, New Zealand.*

TANSLEY, T. L., attorney, Eastern Engineering Co., *Montreal, Que., Canada.*

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WHELAN, W. MILLER, engineer, Fairbanks, Morse & Co., *Beloit, Wis.*

WITHEY, WALTER WILLIAM, superintendent of service and repair department, Magnus Motors, *Wellington, New Zealand.*

WOOD, WALTER G., salesman, Botterill Automobile Co., *Salt Lake City, Utah.*